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ORIGINAL ARTICLES.

On the Marine Gravels at March, Cambridgeshire.

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1. Definition of "March Gravels".

Since the Fenland Research Committee was formed in 1932, several papers have appeared, under its auspices, describing recent research work in the Fen District. The present article is a contribution to the work of this Committee, but describes deposits which are earlier in date than those which have been dealt with so far. The marine gravels have long been known near the town of March in Cambridgeshire, and the object here is to collect what is known up to the present (1934) about this deposit and to discuss its relation to the glacial and implementiferous deposits of southern Fenland and in the neighbourhood of Cambridge. The term "March Gravel" will be used here in reference to the sands and gravels which contain marine organisms and which are found on the "islands" between Peterborough on the west and the "Bedford River", near Manea, on the east.

The work described here was commenced and stimulated by the late Professor Marr, and I am especially indebted to his memory. I am also most grateful to Professor W. J. Sollas for his advice and help, and to Mr. F. M. Walker, of Manea, whose knowledge of the local sections has been of the greatest assistance, for his generous loan of specimens for identification. I am also glad to take this opportunity to express my thanks to Professor W. B. R. King and

to Mr. A. G. Brighton for affording me facilities for working in the Sedgwick Museum at Cambridge; to the late Dr. F. L. Kitchin of the Geological Survey and to Mr. L. R. Cox of the British Museum and to the authorities of the museums at Peterborough, Wisbech, Norwich, and King's Lynn for their help and loan of specimens; to Dr. W. A. Macfadyen for identification of foraminifera; to Mr. Miles Burkitt and Dr. K. S. Sandford for help with the implements; to Dr. Lang and Miss D. M. A. Bate for their help with the mammalian remains; and to all those whose help in the field has been of the greatest assistance.

2. Field Occurrence.

The area described in this article is restricted to southern Fenland, because the fossiliferous deposits found here form a topographically isolated unit, and other similar fossiliferous deposits in Fenland will be dealt with separately at a later date. As far as possible, the place-names used in this article will be those of the One-inch Maps of the Ordnance Survey, but a sketch-map has been prepared to show the position of the pits near March. In the list of the fossiliferous sections which follows, the numbers of the localities are quite arbitrary, and are those which happen to have been used in the field. Many of the pits were only temporarily open, and it is therefore considered important to define their position accurately but in any case it is hoped that the map and list may help investigators who might want to visit any of the pits in the future.

List of March Gravel Sections.

1. *Whittlesey.*—Brickworks almost exactly one mile east of Whittlesey, and between the Whittlesey–Eastrea road and the railway.
2. *Whittlesey.*—" Saxon " Brickworks, about 1 mile to the west.
3. *Whittlesey.*—Bundy's Brickworks, south of the railway and about 1 mile south-east of Whittlesey.
4. *Whittlesey.*—Large gravel pit immediately north of the Angle Bridge–Whittlesey road, and east of the branch line to Bundy's.
5. *Whittlesey.*—Victory Brickworks, west of Whittlesey.
6. *Fletton.*—Large disused brickworks about ¼ mile due south of Fletton Church.
7. *Yaxley.*—Brickworks ¼ mile south-east of the village.
8. *Eye.*—Disused brickworks immediately north of the station.
9. *Fengate.*—Williamson's Pit, one mile east-north-east of Peterborough Cathedral.
10. *Coates.*—Gravel Pit ½ mile east of the village, at junction of the Eldernell side-road with the March–Whittlesey main road.
11. *Manea Railway Station.*—Sear's Pit, ½ mile north of the station and on the west side of the road to Fodder Fen Common.

13. *Honey Bridge.*—On the Sixteen Foot Drain, 2 miles east of Doddington. Gravel pit immediately across the road from the bridge.

14. *Holly House Farm.*—1½ miles from No. 13, to the east of the farm and on the north side of the Forty Foot Drain.

17. *Wimblington Common.*—Griffin's Pit, in the middle of the "common" and east of Common Farm.

18. *Brown's Hill.*—Between Common Farm and the Sixteen Foot Drain. Known locally as Peacock's Pit.

19. *Brown's Hill.*—Redhead's Pit, immediately adjoining Peacock's Pit, on the east side of the hedge.

20. *March Old Church.*—Ogden's Pit, between the main road and the small lane going north-east. The pit is more easily approached from the lane.

22. *Doddington.*—Dack's Pit, 1 mile north-west of Doddington, along the turning to the west from the lane which runs north beside the Workhouse.

23. *Carter's Bridge.*—Thorn's Pit, on the south side of the earth-road leading to West Moor, about ¼ mile off the main road to Chatteris and about ½ mile south-south-west of Carter's Bridge.

26. *March.*—Bennett's Pit, along "The Avenue", about ½ mile north of "Old Church".

28. *Linwood Farm.*—To the west of the main road, and about half-way between Wimblington and March "Old Church". The sections were across the fields half-way between Linwood House and Ransonmoor Grange.

29. *Honey Hill.*—Clarke's Pit, half-way between Honey Bridge and Holly House Farm.

30. *Manea.*—Guy's Pit, about 1 mile north-east of the village, on the west side of the road to Bond's Farm and almost opposite the entrance to Bedlam Farm.

41. *Wimblington.*—Fisher's Pit, on the east side of the main road to March, just north of Eastwood End and about ¾ mile north of Wimblington.

44. *Gray's Moor.*—About 1½ miles north of March railway station.

45. *Hobb's Bridge.*—About ½ mile to the south-east of the bridge across the fields.

48. *Hobb's Bridge.*—Pit beside the main-road to March, ½ mile south of Hobb's Bridge.

The numbers omitted from this list refer to sections which do not concern the present paper. The names by which the pits are known locally, e.g. Fisher's Pit (No. 41), have been added to the list in order to facilitate local inquiry.

Height.—The amount of submergence represented by the March Gravel can be estimated to some extent by the height to which marine shells can be traced. Shells were found at all heights from about O.D. level up to about 6 m. (20 feet) O.D. For instance, fragments of "*Littorina rudis*" occured at about 6 m. (20 feet) at the

brickyard east of Whittlesey (No. 1) and *L. littorea* at about the same height at the Victory Brickyard, Whittlesey, but no marine shells were found at about 9 m. (30 feet) at Fletton nor at about 24 m.

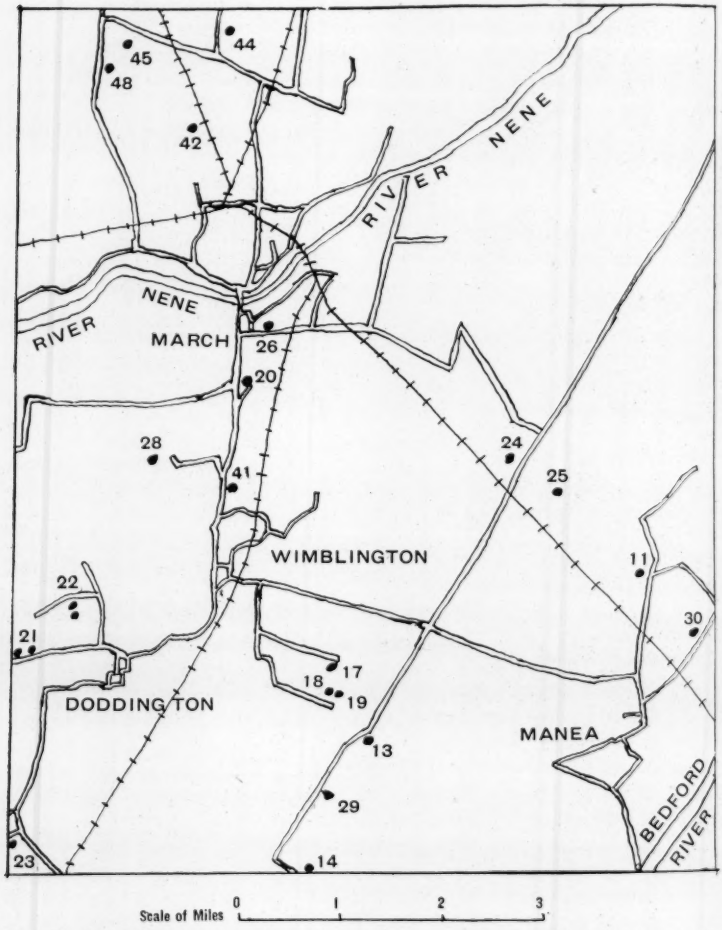

Fig. 1.—Map showing position of sections near March. The Numbers refer to the List of Sections, except numbers 24, 25, and 42, which are mentioned under glacial deposits.

(75 feet) at Yaxley and, although it would be unsafe to base any wide conclusions on experience in these four pits alone, the upper limit for marine shells in the southern Fens appears to be at about

9 m. (30 feet), as no marine shells have been found, at least above the 50 ft. contour, either in the valley of the Nene above Peterborough or up the valley of the Cam towards Cambridge.

It will be noticed that no accurate levels have yet been mentioned. Exact levelling work is particularly long and difficult to do in the Fens, and so far it has been considered that the amount of work involved would not be justified. The main reason for this conclusion is that in the Fen "islands" we appear to be dealing with off-shore sandbanks, as all the fossiliferous localities are too far out from the "edge" of the Fens to have been near high-water mark of the time at which the deposits were laid down, and a consideration of the fauna supports this conclusion, and the large-scale false-bedding which occurs in some of the pits also strongly confirms this idea. In other words, it is considered that the gravel on the "islands" was formed on sandbanks which would have been dry at low tide, like those in the existing Wash. If the tidal range of the time was the same as it is now, about 6 m. (20 feet), and if low-water mark of the time was about the present 7 m. (23 feet) level, as is suggested by Seeley's report of *Pholas*-borings at about this level at Wimblington (1866, p. 473), the mean-tide mark at the time of the formation of these gravels would be the present level of 10 m. (32 feet). Since present mean tide-level may be taken for calculations of this sort as coincident with Ordnance Datum level, these considerations point to a displacement of sea-level of about 7 m. (22 feet).

These are the only data at present available in the southern Fenland from which the amount of submergence can be worked out, but when other parts of Fenland are taken into account it can be seen that the submergence may have been somewhat greater. Skertchly stated in the Fenland Memoir (1877, pp. 184, 198) [1] that the gravel which he considered to be of marine origin on the western border of the Fens was found at about 14 m. (46 feet) at Heckington, at about 17 m. (56 feet) at Sleaford, and at about 18 m. (60 feet) at Billinghay, but it is by no means certain which, if any, of these gravels are truly marine. They were reported to be unfossiliferous, but even if they were proved to be marine they might possibly have been formed by storm-beach action. The evidence is, however, more definite from the Nar Valley and from Hunstanton, in eastern Fenland, where the Nar Valley Clay has been traced to about 15 m. (approximately 50 feet) by the Geological Survey (1893, p. 81) and the fossiliferous Hunstanton Gravel to 12 m. (40 feet), at which height it was exposed (in 1933) in the Gasworks Pit at Hunstanton. As will be shown at a future date, the Nar Valley Clay and the Hunstanton Gravel are considered by the writer on palaeontological grounds to be contemporaneous with the March Gravel and, assuming that the Nar Valley Clay

[1] See Bibliography at the end of this article.

at its upper limit may have been formed near the high-water mark of the time, a general average figure for this submergence in Fenland may be taken as 12 m. (40 feet). It is true that the Nar Valley Clay has been reported from greater heights than this, but enough fieldwork has not yet been done to discuss this point further. It may be taken as certain that this submergence in Fenland has not been less than 10 m. (32 feet) and may have been as much as 12 m. (40 feet) or even more.

Details of Sections.—No attempt will be made to describe all the sections in the above list, as this would involve unnecessary repetition and only the more important ones will be given in detail.

Eye.—Section No. 8 on the list. This locality is too far west to appear on the map, and it might be explained that all the westerly localities near Peterborough and Whittlesey were excluded because it was thought that their inclusion would make the map too small in scale to be of any real value.

By way of general description there is little to add to that given by Professor Marr and Professor King (1928, pp. 210–12). The sequence of the Pleistocene beds where developed to their greatest thickness is :—

	Feet.
2. Brickearth, light brown, sandy, with wisps of stones .	6
1. Sand and gravel, with well-rounded pebbles, false-bedded on a large scale, and containing abundant marine shells, including *Mytilus edulis*, *Macoma balthica*, *Macoma calcarea*, and *Isocardia humana*, together with other common forms	15
Base not seen.	

Bed 2.—This brickearth is very similar to that seen at Yaxley and many other places, and is unfossiliferous except near the base, where it contained *Littorina littorea*, *Cardium edule*, and *Macoma balthica*, but it is obvious that these shells were derived from the underlying gravel. In colour, the brickearth is always more light-coloured on its upper part than in the lower 2 or 3 feet, presumably on account of weathering. It rests with complete unconformity on the underlying beds, as the Pleistocene gravel is found beneath it in the north-western part of the pit, whereas in the north-eastern part the brickearth rests directly on the Oxford Clay. This unconformity is not always apparent over the Pleistocene gravel, as the top of the gravel is sometimes disturbed, and even locally stained by the same dark-brown colour as the base of the brickearth. This deposit will be discussed further in that part of this article which deals with the glacial beds.

Bed 1.—The sand and gravel is often highly fossiliferous in this pit and at first an attempt was made to collect the marine fauna layer by layer, but it was soon found that no faunal difference could be discovered even between the top and bottom of the section, and it is in fact impossible to trace out any particular layer owing to the

huge scale of the false-bedding. It might, however, be mentioned that *Macoma calcarea*, indicating a colder climate than that of the present day, was only found at the top of the marine gravel, but as that species is only represented so far by two valves at this section, its position is of no great importance, unless more are found. It should be mentioned that Marr and King (1928, p. 211) suggested that "the abundance of small marine shells in the highest part of the deposit may indicate the oncoming of cold conditions", and it is possible that only the top part of this section may represent a cold climate, but at the same time no shells indicating warmer conditions than those of the present day have been found lower down. The marine gravel also contains driftwood, and mammalian bones in a mineralized condition have been obtained from the foreman but were not seen in situ. "Silt B" (see under *Foraminifera*) was locally developed near the top of the marine gravel.

No implements have been seen in this pit, but they should be easy to detect, as the pebbles both in the brickearth and near the top of the marine bed are generally of smaller size than the worked flints found elsewhere in the district. Also the pebbles in the marine gravel are rather well rounded, and worked flints should be conspicuous.

It might be worth mentioning that the foreman at Eye reported that a human skull was found in 1922, but it was broken up and is now incorporated in a large tip heap. According to his account the skull was found 10 feet down from the surface and 4 feet above the floor of the gravel pit, but it is difficult to estimate the value of this statement.

Wimblington Common.—Section No. 17 on the list and map. The thin capping over the marine gravel seems to vary greatly in composition, but the general section is as follows:—

	Feet.
2. Black soil with pebbles, sometimes giving place to thin clay or brickearth	2
1. Sand and gravel with marine shells throughout, with thin wisps of sand containing small freshwater shells. *Corbicula* and *Macoma calcarea* have both been found in the gravel, and a palaeolithic implement is also believed to have come from the gravel . . .	7
Base not seen.	

Bed 2.—Where the brickearth occurs, it is light in colour and not so sandy as at Eye, but it has the same tough consistency. A thin impersistent layer of dark-brown clay occurs under the black soil at the south-west corner of the pit, but none of these overlying beds is well developed.

Bed 1.—The pebbles in the gravel here consist largely of rather angular flint, and limestone is rare to absent, although at Eye about 50 per cent of the gravel consists of limestone. The most common shells are *Mytilus edulis* and *Macoma balthica*, and *Corbicula consobrina* and *Macoma calcarea* are only represented by one single

valve each. The bedding of the gravel here is too obscure to make out any climatic sequence, but the climatic significance of finding the "cold" *Macoma* and *Corbicula*, usually considered warm, apparently in the same gravel will be discussed under *Corbicula*. The impersistent beds of sand containing freshwater shells apparently also contain *Mytilus*, and these present a more difficult problem than the presence of *Corbicula*.

A worked flint flake was found by Mr. Walker and myself on the tip heap near the south-west end of the pit, and the matrix adhering to this shows that it probably came from the gravel. Its form has been considered to suggest Levallois work, and it will be referred to again when discussing other implements from this district. Other pieces of flint which may have been worked by man were found in the marine gravel, but only so far from near the top of the deposit, but no date can be assigned to them.

Manea.—"Sear's" Pit, Section No. 11 on the list and map. Special mention is made here of this pit, because *Corbicula* is by far the most common shell, and there is no doubt whatever that at this locality it occurs with an otherwise "normal" marine fauna. The pit is now unfortunately filled in and grassed over, but the section seen (in 1931) was :—

	Ft.	In.
4. Black subsoil with numerous pebbles . . .	2	0
3. Coarse chalky gravel, few shells		10
2. Sand, with a few shells		6
1. Band of very shelly gravel		2
Sand.		

Bed 4.—The black "soil" is occasionally let down into the underlying beds in what appear to be channels, and is almost certainly connected with the much later Fen Beds (possibly Bronze Age or Neolithic). No actual proof of its age was found.

Beds 1, 2, and 3.—No distinction could be made between these three on palaeontological grounds, and *Corbicula* occurred throughout associated with *Mytilus edulis, Anomia ephippium, Cardium edule, Corbula gibba, Pholas dactylus,* and *Turritella communis*. *Corbicula* is important at this locality, and will be discussed again, but it must be mentioned that the shells from this pit differ from *Corbicula* found under freshwater conditions near Cambridge.

These three pits are the most important in the district, and none of the other pits show any features not shown by these three. As far as the relations of the marine bed are concerned, the only Pleistocene deposit seen in section during the present fieldwork with the marine bed was the brickearth and, where both deposits are developed in the same pits, the invariable sequence seen in the field is :—

2. Brickearth.
1. Marine March Gravel.

The relation of the Chalky-Jurassic Boulder Clay to the March

Gravel will be discussed in the section dealing with the glacial deposits, but unfortunately their relation cannot be seen directly in section at the present time. The March Gravel has been described by many geologists who worked on it during the last century and, although in some of the sections seen by them the marine gravel rested directly on the Jurassic clays, in other sections this marine gravel was seen to overlie boulder clay. Professor Seeley (1866, p. 470) showed that boulder clay "with the usual characters" underlay shelly gravel at Pape's Brickyard, White Lion Lane, March, and also at Hutchinson's Brickyard at March, and since his date Professor Judd (1875, p. 470), Skertchly (1877, p. 192), Jukes-Browne (1878, pp. 58–60), and S. V. Wood (1882, p. 698) have all expressed their opinion that the boulder clay is earlier than the marine gravel, and in the Memoir of the Geological Survey which includes March sections are mentioned which also confirm this relationship between the two deposits.

3. Fauna.

Foraminifera.—The only locality at which foraminifera have been found so far is Eye, though it is probable that most of the sections in the marine gravel would yield them if a search were made. The list of species and the discussion which follows are taken from the report kindly supplied by Dr. Macfadyen.

	Silt. B.	*Gravel.* D.
Indigenous Species :—		
Reussella spinulosa var. *glabrata* Cushman	X	L
Bigenerina agglutinans d'Orbigny	—	I
Bulumina pupoides d'Orbigny	I	V
Bulumina affinis d'Orbigny	I	—
Bulumina marginata d'Orbigny	I	I
Buliminella elegantissima (d'Orbigny)	I	V
Virginulina fusiformis (Williamson)	X	X
Bolivina aff. *nobilis* Hantken	I	V
Bolivina dilatata Reuss ?	X	X
Bolivina pseudoplicata Heron-Allen & Earland	X	L
Bolivina variabilis (Williamson)	X	L
Crassidulina crassa d'Orbigny	I	—
Lagena clavata (d'Orbigny)	I	I
Lagena globosa (Montagu)	—	I
Lagena hexagona (Williamson)	X	V
Lagena lucida (Williamson)	I	I
Lagena laevis (Montagu)	V	V
Lagena lineata Williamson	—	I
Lagena perlucida (Montagu)	I	I
Lagena reticulata (Macgillivray)	—	X
Lagena scalariformis (Williamson)	I	I
Lagena semistriata Williamson	I	I
Lagena substriata Williamson	—	I
Lagena sulcata Walker & Jacob	I	I
Nodosaria communis (d'Orbigny) ?	I	I
Marginula costata (Batsch)	I	I
Marginulina cf. *bullata* Reuss	I	I

	Silt. B.	*Gravel.* D.
Indigenous Species :—		
Cristalleria gibba d'Orbigny	I	I
Guttulina lactea (Walker & Jacob)	I	I
Sigmomorphina williamsoni (Terquem)	I	—
" *Polymorphina* " Sp.	—	I
Uvigerina angulosa Williamson	X	X
Uvigerina asperula Czjzek	I	—
Globigerina bulloides d'Orbigny	—	I
Patellina corrugata Williamson	I	—
Discorbis obtusus (d'Orbigny)	L	L
Discorbis praegeri (Heron-Allen & Earland)	—	I
Lamarckina haliotidea (Heron-Allen & Earland)	—	I
Cibicides lobatulus (Walker & Jacob)	X	X
Rotalia beccarii (Linne)	C	C
Nonion depressulus (Walker & Jacob)	C	C
Nonion pauperatus (Balkwill & Wright)	—	I
Elphidium excavatum (Terquem)	L	X
Elphidium incertum (Terquem)	X	I
Elphidium incertum var. *clavatum* Cushman	X	X
Elphidium macellum (Fichtel & Moll)	X	X
Elphidium oceanense (d'Orbigny)	I	I
Total, 47 species	36	40

	Silt. B.	Gravel. D.
Ostracoda	X	L
Foraminifera derived from the Chalk :—		
Bulumina murchisoniana d'Orbigny	I	—
Bolivina quadrilatera (Schwager)	—	I
Pseudotextularia globulosa (Ehrenberg)	X	X
Eouvigerina cretacea (Heron-Allen & Earland)	V	V
Nodosaria cf. *aculeata* (d'Orbigny)	I	—
Nodosaria communis (d'Orbigny)	I	I
Glandulina laevigata d'Orbigny	I	—
Cristalleria aff. *crepidularis* Roemer	I	—
Cristalleria rotulata (Lamarck)	—	I
Globigerina aspersa (Ehrenberg)	V	X
Chalk spheres	X	V
Foraminifera derived from the Jurassic :—		
Frondicularia tenera (Bornemann)	I	I

(I, very rare ; V, rare ; X, frequent ; L, common ; C, abundant.)

Echinodermata :—
Spatangus purpureus Müller
Echinocardium cordatum (Pennant) } ? both species present.

Silt B.—Somewhat clayey silt ; the washed residue was brown silt.

False-bedded Gravel D.—The sample was a mixed one taken mostly from the finer bands and lenticles of sand in the gravels. The washed residue consisted of sand of varying grade.

As shown above, the two samples yielded almost identical foraminiferal faunas, and consequently they may be considered together. Compared with the foraminifera yielded by the later Fenland deposits of Buttery Clay and Silts, there are some interesting differences apparent. As regards the indigenous fauna, there are

a number of forms missing from the March Gravels which are often present and sometimes common in many of the later deposits, as species of *Trochammina* (particularly), *Cornuspira*, *Quinqueloculina*, *Triloculina*, and *Planorbulina*, and also *Lagena williamsomi*; while *Lagena laevigata* is much rarer. Of *Discorbis* several not uncommon species are missing.

On the other hand, *Uvigerina angulosa*, the reticulate *Lagena* species *L. hexagona* and *L. reticulata*, and *Elphidium macellum* are frequent instead of being rare or very rare. Of other species present in the March Gravels which have not so far been recorded by Dr. Macfadyen from the later deposits are *Reussella spinulosa* var. *glabra*, *Cristalleria gibba*, *Marginulina* cf. *bullata*, and *Nonion pauperatus*; but these occur in such small numbers that their evidence may perhaps not be of much significance.

There are two other points of difference. Two of the commonest species, *Rotalia beccarii* and *Nonion depressulus*, often reach a considerably larger size in the March Gravels than in the later beds; and secondly, there are found in the Gravel sample D (but not in Silt B) a number of specimens of those two species and also of *Discorbis obtusus* and *Elphidium* Spp. which are distinctly hirsute. The significance of this last observation is not clear, but the other differences may, perhaps, be accounted for, in part at least, by postulating a purely marine origin for the March Gravels, instead of the very markedly brackish, or at lest estuarine origin of the later deposit. This may be supported by the presence in the March Gravels of numerous spines of an irregular echinoid, which were found in the washed residue.

Mr. A. G. Brighton has kindly examined the echinoid spines, which appear to belong to an irregular echinoid. They may be compared closely with similar spines of both *Spatangus purpureus* and *Echinocardium cordatum* (Pennant), which are common species in the present-day North Sea.

The indigenous species (of Foraminifera) are all living forms, so that they give no assistance in dating the deposit; nor do they give any indication of a climate different from that of the present day.

Of the derived foraminifera the Chalk species are rather more numerous than is usually found in the later deposits, but the bulk of the specimens is of the same few species. The single species derived from the Jurassic is a common small form in that formation.

Dr. Macfadyen's specimens were deposited at the Sedgwick Museum, Cambridge.

The following two species are reported in the Survey Memoir (1893 p. 110) on the authority of Rose and Harmer, and were presumably found near March, though no exact locality is given :—

Cirripedia.

Balanus porcatus da Costa.

Brachiopoda.

Rhynchonella psittacea Chemnitz.

Pelecypoda and Gasteropoda.

This part of the list has been compiled partly from material collected in the field, and partly from specimens examined in the British Museum, Geological Survey Museum, Sedgwick Museum at Cambridge, and the museums at Peterborough, Norwich, Wisbech, and King's Lynn. Species are also included with some reserve which have been reported by early observers, and Professor Sollas kindly gave me shells from March which had been collected by Professor Bonney.

With one or two unimportant exceptions, the nomenclature used here is that of Mr. R. Winckworth's list, "The British Marine Mollusca," published in the *Journal of Conchology*, xix, 7, June 1932, 211–252. As some of the genera considered correct by Mr. Winckworth may be unfamiliar to most readers, less correct generic names which are more widely known are added in parentheses.

The shells found during the course of the present fieldwork are at the University Museum, Oxford, with the exception of a few of the shells, including some *Corbicula*, which are in the possession of Mr. F. M. Walker of Manea.

The abbreviations used in this list are :—

M. Published in a previous list of March fossils, but specimens not necessarily seen in existing museum collections, nor confirmed in the field.

BM. British Museum, South Kensington.

GSM. Collection at the Geological Survey Museum.

S. Sedgwick Museum, Cambridge.

N. Norwich Museum.

P. Peterborough Museum.

W. Wisbech Museum.

Mh., followed by a number. Found in the field, the number referring to those used for sections in this paper.

LAMELLIBRANCHIA.

Anomia ephippium Linne	? BM.
Monia (*Anomia*) *patelliformis* (Linne)	N., Mh. 8.
Mytilus edulis Linne	BM., GSM., S., N., Mh. 8, 17, 18, 19, 48.
Modiolus modiolus (Linne)	M.
Ostrea edulis Linne	BM., GSM., S., N., Mh. 8, 20, 45, 48.
Astarte sulcata (da Costa)	BM., GSM.
Astarte montagui Dillwyn	BM., S.
Astarte borealis Chemnitz	GSM., N.
Glossus (*Isocardia*) *humanus* (Linne)	S., Mh. 8.
Cyprina islandica Linne	S.
Scrobicularia plana (da Costa)	BM., GSM., S., Mh. 8, 19, 41.
Tellina obliqua J. Sowerby ?	S.
Macoma balthica (Linne)	BM., GSM., S., N., Mh. 2, 3, 11, 17, 18, 20, 23, 41, 44, 45, 48.

Macoma calcarea Chemnitz	S., ? Mh. 8, 17.
Spisula solida (Linne)	BM., GSM., Mh. 8.
Spisula elliptica (Brown)	S., N.
Spisula subtruncata (da Costa)	BM.
Cardium edule Linne	BM., GSM., S., N., Mh. 3, 8, 17, 18, 20, 23, 48.
Mya arenaria Linne ?	M., S., N.
Mya truncata Linne	BM., GSM., S., N., W., Mh. 17, 18, 20, 48.
Aloidis (*Corbula*) *gibba* (Olivi)	BM., S., Mh. 8, 11.
Pholas dactylus Linne	GSM., S., Mh. 8, 11, 17.
Zirfaea (*Pholas*) *crispata* (Linne)	M.

SCAPHOPODA.

Dentalium entalis Linne	GSM.

GASTROPODA.

Emarginula cf. *reticulata* (Sowerby) (*E. fissura* (Linne))	GSM.
Gibbula cineraria (Linne)	BM., GSM.
Lacuna crassior (Montagu)	BM., GSM., N., Mh. 17, Bonney Coll.
Lacuna vincta (Montagu) (*L. divaricata* (Fabricius))	M.
Littorina saxatilis (Olivi) (*L. rudis* (Maton))	BM., Mh. 1.
Littorina littorea Linne	BM., GSM., S., Mh. 3, 4, 5, 8, 20, 41, 48.
Rissoa parva (da Costa) var *interrupta* Adams	S. (from Mh. 8).
Hydrobia ulvae Pennant	S. (from Mh. 8).
Natica catena (da Costa)	BM., ? S., N.
Natica alderi Forbes	BM., GSM., S., N., Mh. 11.
Natica montagui Forbes	Mh. 20.
Natica affinis Gmelin	N.
Natica pallida Broderip & Sowerby ?	N.
Amauropsis islandica Gmelin	BM., GSM., S., N., Mh. 18, 20, 41.
Velutina undata J. Smith	M.
Clathrus (*Scalaria*) *clathrus* (Linne)	GSM., S., N.
Turritella communis Risso	BM., GSM., S., N., Mh. 8, 9, 20, 41, 48.
Aporrhais pes-pelecani Linne	BM., GSM., S., N., ? Mh. 11.
Buccinum undatum Linne	BM., GSM., S., N., Mh. 4, 17, 18, 20, 41.
? var. *coerulea* G. O. Sars	BM.
? "*Fusus*" Sp.	W.
Ocenebra erinacea (Linne)	BM.
Trophon clathratus (Linne)	S.
Trophon truncatus (Ström)	BM., GSM., S., N., Mh. 20.
Nassarius (*Nassa*) *reticulatus* (Linne)	BM., S., N.
Nassarius (*Nassa*) *pygmaeus* (Lamarck)	Mh. 8.
Nucella (*Purpura*) *lapillus* (Linne)	BM., GSM., S., W., P., Mh. 17, 18, 20.
Lora (*Bela*) *turricula* (Montagu)	BM., GSM., S., N.
Lora (*Bela*) *trevelliana* (Turton)	BM., N.
Lora (*Bela*) *pyramidalis* (Ström)	BM., GSM., S., N.
Lora (*Bela*) *rufa* (Montagu)	BM., N., Bonney Coll.
Philbertia (*Clathurella*) *linearis* (Montagu)	BM.
Retusa truncatula (Bruguiere)	BM.

Notes on Certain Molluscan Species.—It is important that one extinct species is here included in the March Gravel list, and one or two facts must be noted about this species, and about the occurrence of *Corbicula*.

Tellina obliqua J. Sowerby, 1817.

This species has not been included in lists from the March Gravel before, but one large valve in the Sedgwick Museum at Cambridge is labelled with this name, and certainly agrees with S. V. Wood's figure (*Crag Mollusca*, vol. 2, 1850–1856, plate 21, fig. 7 *c*). The shell at Cambridge resembles *Tellina crassa* Pennant, but differs from that species in its dentition, and also *T. obliqua* is much thinner in shell, though as large as *T. crassa*. The Cambridge shell should at least be referred provisionally to *T. obliqua*.

According to Wood, *T. obliqua* ranges from the Coralline Crag to the Chillesford Crag, and of its continuation into the Pleistocene he says (*Supplement to Crag Mollusca*, part 2, 1874, p. 152); "[we] still meet with *obliqua* in the Middle Glacial sands [of Yarmouth] and at Bridlington, but it has not yet been met with in any Post-glacial bed, or in any of the English Newer Glacial, or in any of the Scotch beds." At a later date one valve was reported from Laceby, in Yorkshire (*Memoirs of the Geological Survey*, Geology of Holderness, 1885, p. 71), and the species appears to be extinct at the present day.

Corbicula consobrina Caillaud, 1823.

As regards the nomenclature of this species, Major Connolly has shown (*Proc. Mal. Soc.*, xix, 1930, 43) that the name *fluminalis* Müller refers to *C. artini* Pallory (1902), but all the shells dealt with in this paper should be referred to *C. consobrina* Cailliaud (1823), a conclusion also reached by Miss Gardner (1932, p. 61), and although it is unfortunate that the name *fluminalis* has been used so extensively for the Quaternary shells of this country, the name *consubrina* should be used in future.

Corbicula consobrina was found in the field in the following sections: Bundy's (No. 3), Manea (No. 11), Honey Bridge (No. 13), Holly House Farm (No. 14), Wimblington Common (No. 17), Brown's Hill (No. 18), Carter's Bridge (No. 23), and "Guy's" pit at Manea (No. 30). It is, however, very scarce at most of these pits, and has only been found in any numbers at "Sear's" pit at Manea (No. 11) and at Carter's Bridge (No. 23). This is unfortunate, because the shells from Manea were found to differ from those found under typical freshwater conditions near Cambridge, and it would be important to find out whether *Corbicula* found associated with marine shells at other sections would also differ from *Corbicula* from the freshwater sections. In detail, the difference between the Manea shells and the Cambridge shells can be expressed by the length/height ratio. About 150 shells were measured from the

Manea pit, some of these being collected in the field, and some being kindly lent for measurement by the authorities of the Sedgwick Museum, and the height (measured from the umbones to the ventral margin) was expressed as a percentage of the length (measured from the anterior to the posterior margin), and it was found that for larger shells the average ratio was slightly greater than for smaller shells, thus :—

Height of Shell.	*Length/height ratio.*
mm.	per cent.
24·6 to 12·0	95·0 to 97·6
12·0 to 6·5	92·9 to 93·9

Rather different results were obtained from *Corbicula* from various sections near Cambridge (about 370 being measured), and those labelled Rodney Brewery were typical :—

Height of shell.	*Length/height ratio.*
mm.	per cent.
20·5 to 12·7	95·8
13·9 to 8·6	85·8

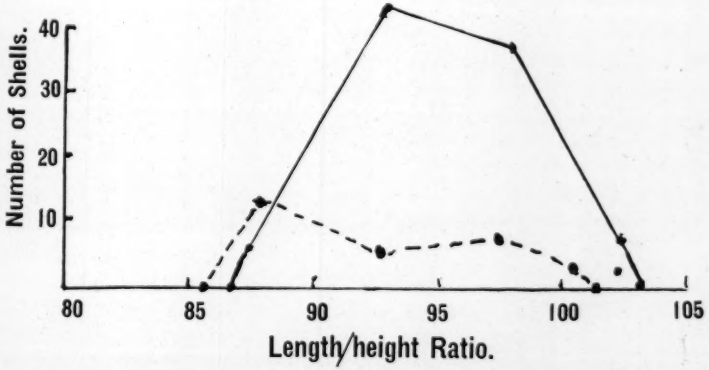

FIG. 2.—Variation Curve for *Corbicula consobrina*, size over 12 mm.
From Manea. ————
From Rodney Brewery, Cambridge. – – – – – –

Other Cambridge shells came from Barnwell and Barrington and, although the difference from the Manea shells was not always so great as in the case of Rodney Brewery, *it was found to be an invariable rule that the smaller Corbiculae from Cambridge had a smaller height in proportion to their length than the smaller Corbiculae from the marine bed at Manea.* These results are shown diagrammatically in Figs. 2 and 3 in the form of variation curves, in each case the continuous line representing the shells from Manea, the broken line those from Rodney Brewery, Cambridge. The important point is that the peak for these two localities is in approximately the same place for shells of larger size, whereas for shells of smaller size the peak for the Cambridge shells comes distinctly to the left of that for the Manea shells.

It is instructive to compare these variation curves with those published for *Corbicula* by Miss Gardner in her monograph on the Fayum, Egypt (1932, p. 63). Miss Gardner found that three species of *Corbiculae* lived in the Pleistocene Lake which occupied the Fayum depression, *C. vara*, *C. artini*, and *C. consobrina*, but that *C. vara* became extinct in the Fayum before Neolithic times at that place. By comparison with the Pleistocene shells from Cambridge, Miss Gardner also found a " general similarity of the curves for the British Pleistocene and modern African *Corbiculae* " rather than a similarity for the British Pleistocene with the Pleistocene shells of the Fayum, and this is also true of the shells from Manea, which in this respect resemble the Cambridge shells, only differing slightly in measurement. It must be emphasized that it would be unsafe to base any wide conclusions on this difference, as enough shells for satisfactory measurement have only been obtained so far from one " marine " pit (Manea), and it is not known whether the apparent

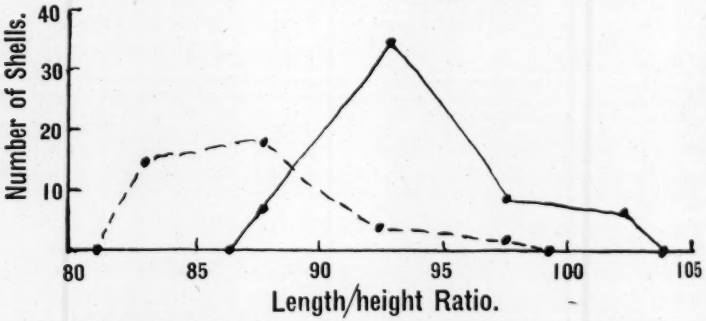

FIG. 3.—Variation Curve for *Corbicula consobrina*, size under 12 mm.
From Manea. ————
From Rodney Brewery, Cambridge. - - - - - - -

difference between " marine " and " freshwater " *Corbiculae* is constant. It is of course possible that the abnormality of the Manea shells is a local racial phenomenon. In order to test this point, specimens of *Corbicula* from Carter's Bridge (No. 23) were measured, but unfortunately only twelve valves could be obtained for measurement (from Mr. Walker), and no fossiliferous deposit is at present exposed in this pit. As far as these measurements go, they are of typical " freshwater " type; the results being as follows :—

Height of Shell.	*Length/height ratio.*
mm.	per cent.
13·3 to 11·0	94·1
10·0 to 8·6	85·1

Cardium edule and *Macoma balthica* have been found in this pit by Mr. Walker, apparently associated with *Corbicula consobrina*, but the *Cardium* specimens are smaller than those from any other

of the March pits, and it is considered possible that the deposit at Carter's Bridge represents the estuarine facies of the *Corbicula*-deposits near Cambridge.

At first sight the fact that the Carter's Bridge shells belong to the " freshwater " Cambridge type rather than to the " marine " Manea type, in spite of the fact that they are associated with *Cardium* and *Macoma*, suggests that the Manea shells only show racial modification. It is, however, probable that the Manea shells differ in age from the Cambridge shells, because *Corbicula* in the March area generally appears to be associated with the rather cold marine fauna of the March horizon, whereas the Cambridge *Corbiculae* are associated with a warm (*Hippopotamus*) fauna (Marr, 1917, p. 67), and the writer does not believe that the two can be contemporaneous, in spite of the fact that *Corbicula* is found in both. As far as the implements go, they also confirm this conclusion, as the flake suggesting Levallois work was found at the Wimblington Common pit in which *Corbicula* was also found, whereas the Cambridge *Corbicula*-beds are believed to be of Chellean date (Marr, 1917, p. 67).

The specimens of *Corbicula* from Manea are sometimes more worn than those from Cambridge, although it was found by experiment that this did not affect measurement. At the same time about half the specimens from Manea were quite fresh, even showing the delicate cross-striae on the lateral teeth, but the question as to whether the Manea shells are more worn than those from Cambridge only affects the issue as to whether they lived with the marine fauna or not, and does not affect their actual date, because the Manea deposit in which they are found may be later than the Cambridge (Barnwell) deposit, whether they were derived as dead shells or whether they became adapted to live under marine conditions. As regards the possibility of *Corbicula consobrina* living with *Cardium edule*, it has been shown by Miss Gardner (1927, p. 400) that *Cardium edule* has recently been introduced accidentally into the existing lake which occupies the bottom of the Fayum depression, and that *Corbicula consobrina* and *Cardium edule* both live in the same lake at the present time. Whether it is possible for this *Corbicula* to adapt itself still further and live with a true marine fauna (like that found fossil at Manea) can only be shown by future work.

Climatic Equivalent of the Marine Fauna of the March Gravel.

It has been noticed by several of the earlier workers that the marine fauna from March represents rather colder conditions than those of the present day. Professor Seeley described the shells as of " arctic aspect ", but in his day any shell like *Macoma calcarea* was described in this way without any consideration of the faunal association as a whole. Searles Wood (1872, p. 29) mentioned that two species from March no longer inhabit British Seas, and later added the information

that *Macoma calcarea* (recorded by him as *Tellina lata*) had also been found (1879, pp. 53, 55), and in the Rutland Memoir of the Geological Survey the significance of *Cyprina islandica* is pointed out (1875, p. 251). In none of these publications is there any report of shells from the March Gravel representing conditions warmer than those of the present day. The study of the shells recorded in this paper entirely confirms the earlier work, and in the light of modern knowledge we can say that the approximate present-day climatic equivalent of the marine fauna of the March Gravel is to be found in Southern Norway or Denmark. Occasional shells indicative of rather cold conditions are to be seen throughout the sections from Eye to Manea, and their exact distribution is given in the faunal list, the species in question being *Astarte borealis*, *Astarte montagui*, *Macoma calcarea*, *Amauropsis islandica*, *Velutina undata* (if its occurrence can be confirmed), and *Trophon clathratus*. The occurrence of one or two species, specially *Clathrus* (*Scala*) *clathrus*, suggest that the temperature was only rather cold and certainly not arctic, but no "warm" shells (such as *Cardium tuberculatum*) were found which would contradict the general evidence of conditions slightly colder than those of the present day.

Non-marine Fauna.

Most writers who have described the March Gravel have observed that freshwater shells are occasionally found, and *Unio tumidus* Retzius, *Bithynia tentaculata* (Linne) and *Valvata piscinalis* (Müller) are included in the list in the Survey Memoir (1893, pp. 110, 111). In the field the following shells were found, but their exact specific identification is subject to revision. The numbers after their names refer to the sections, as in the case of the list of marine forms :—

Sphaerium rivicola (Leach) .	Mh. 9, 17.
Pisidium amnicum (Müller) .	Mh. 23.
Succinea putris (Linne) .	Mh. 11.
Limnaea cf. *truncatula* (Müller) .	Mh. 11.
Planorbis cf. *spirorbis* (Linne) .	Mh. 11.
Bithynia tentaculata (Linne) .	Mh. 2, ? 3, 18.

At present there is no satisfactory explanation of the presence of these shells in otherwise normal marine deposits. Sometimes they occur in "wisps" or discontinuous layers of fine silty sand in the marine bed, but the layers in which they are found are not continuous enough to suggest alternation of freshwater with marine conditions. Moreover at Manea (No. 11), they were found in the same thin layer of gravel with *Corbicula* and true marine shells. They have presumably been derived from elsewhere, but it is difficult to imagine by what agency they have been carried. It must be admitted that if these fragile freshwater shells have been derived from a distance, the same may be true of *Corbicula*, although the writer personally believes that *Corbicula* actually lived with the marine fauna and the reasons for this belief have already been stated.

Mammalia.

Mammalian bones have been obtained from some of the pits by Mr. Walker, and a few unidentifiable fragments were found by the writer at Eye. The matrix adhering to the bones suggests that they have come out of the gravel, but unfortunately none have yet been seen in situ. The following list is compiled from identifications by Miss Bate, but unfortunately the material was not good enough for specific identification :—

Manea, Guy's Pit (No. 30).
Bos sp. One fragment of a molar.

Holly House Farm (No. 14).
? *Rhinoceros* sp. Broken proximal end of a radius.
Bos sp. (large). One upper molar.
Equus caballus Linne. One upper molar.
Elephas sp. One centrum of a vertebra, and the proximal part of a radius, including most of the shaft.

Skertchly has recorded Horse and Mammoth from Chatteris, and Mammoth from Whittlesey (1877, pp. 189, 203), and Lydekker *Elephas antiquus* from Whittlesey (*Cat. Foss. Mamm. Brit. Mus.*, 1886, part vi, p. 136), and a tooth of *Elephas* sp. is preserved in the Peterborough Museum and is probably that on which Skertchly's report from Whittlesey is based. It is unfortunate that more is not known about the mammalian fauna which was contemporary with the March Gravel, but of the pits round March at present working that at Holly House Farm seems to be the most promising for the finding of mammalian remains in the future. Unidentifiable remains were obtained by Mr. Walker at the Carter's Bridge Pit. It is also unfortunate that nothing is known about the plants which lived on the adjacent land and which would be contemporaneous with the March Gravel. The only known plant-remains which have been found in connection with the March Gravel are the pieces of driftwood at Eye (No. 8), but samples from this locality have not yet been worked out.

It will be as well to summarize at this point the most important features of the March Gravel.

(1) The March Gravel represents a marine submergence which has affected at least that part of southern Fenland between Peterborough and Manea and therefore presumably the whole of Fenland.

(2) From a consideration of the height and nature of the marine fauna, the amount of this submergence appears to be between 10 and 12 m.

(3) According to Dr. Macfadyen, no colder conditions than those of the present day are exhibited by the foraminifera found at Eye, but the climatic equivalent of the marine mollusca is Southern Norway or Denmark.

(4) The occurrence of *Corbicula consobrina* with the marine forms is undoubted, and can either be explained as having been derived from the Cambridge district, or, as is considered more probable, to have adapted itself to life with the marine forms, in spite of the cold conditions under which they lived.

It might be added that it is considered impossible that a land-glacier could have occupied the Fen basin during the formation of the March Gravel.

4. Relation to Glacial Deposits.

During the course of the fieldwork, true boulder clay was only seen at a few places in the southern Fens, and then never in contact with the marine bed. This is unfortunate, because the true relationship of the two deposits has not been seen in section for a long time. There are really two main questions to be answered about the glacial deposits of the district :—

(*a*) Is there evidence of more than one glaciation ?

(*b*) What is the relation of the glacial deposits to the marine gravel ?

Field Evidence. Yaxley Brickworks.—The most satisfactory section in boulder clay was seen at Yaxley Brickworks, and I would like to take this opportunity to express my thanks to the officials of the London Brick Company and Forders, Ltd. (Peterborough), for permission to enter their premises. This locality (No. 7 on the list given earlier in this paper) is situated on the beginning of the higher ground above the western boundary of the true Fen country. Two interesting sections were seen here, both at the northern end of the pit :—

To the west.

		Feet.
3.	Chalky-Jurassic Boulder Clay . .	12
2.	Chalky clay	0–2
1.	Chalky-Jurassic Boulder Clay . . Oxford Clay	2

To the east.

3. Chalky-Jurassic Boulder Clay.
2. Tongue of brown sandy brickearth.
1. Chalky-Jurassic Boulder Clay.

These two sections are quite near together, but were separated by a grass-grown slope with bushes. In fact the whole section is very overgrown.

The material here described as Chalky-Jurassic Boulder Clay consists of contorted Jurassic clay with erratics of chalk and flint, and the chalky clay in the more westerly section had the appearance of a rolled-out chalk erratic. The junction between this and the Oxford Clay is extremely irregular, the underlying clay is usually contorted, and sometimes the two can only be distinguished by the presence of flint and chalk fragments.

The brown brickearth appears to overlie the Chalky-Jurassic Boulder Clay, but much work would have to be done in clearing the section before one could be at all certain about this.

There are two possible interpretations of the large tongue of brickearth in the boulder clay. Either an erratic of brickearth has been included in the boulder clay, or the brickearth has been forced into the boulder clay from above. It seems more probable that the second of these explanations is correct, because no other erratics of brickearth were seen in the boulder clay in this, or in any other section, and the tongue of brickearth itself slopes upwards at a strong angle and comes out at the surface of the ground.

No detailed description of the petrography of these beds will be given here, because the samples of erratics and of material for possible petrographical work which were collected have not yet been worked out, but it is hoped that these will be dealt with in a future paper.

Hobb's Bridge (near No. 45).—Samples of boulder clay were collected here at a place where material had been dug out of the Twenty Foot River, and again will be dealt with on a future occasion. The material consisted of Jurassic Clay with foreign erratics, including flint.

Crane's Farm, 2 miles north-west of Manea village, and ¾ mile east-south-east of Stonea station, locality No. 25 on the map, but omitted from the list of sections. Mr. Walker of Manea has kindly given me information about a well-section which he saw being dug at this farm, and has lent me striated erratics of chalk and a septarian nodule, and he described the boulder clay here as also containing erratics of oolitic limestone, Carboniferous Limestone, and veins of bluish sand.

Stonea, ¼ mile due north of Stonea station, Section No. 24 on the map, but not included in the list of sections. Mr. Walker was present at the digging of a well at this locality, and reports the following section :—

		Feet.
4.	Soil	1
3.	Blue boulder clay	4
2.	Fine red gravel with *Gryphaea* and Chalk pebbles, but no Pleistocene shells	1
1.	Blue boulder clay, as above. Base not seen.	

L.N.E.R. Works, March.—Large quantities of boulder clay have been dug in recent years at the Railway Works north-west of March station near Longhill Farms, but the visible sections were shallow owing to the level of the water. One section showed :—

		Ft.	In.
3.	Black sandy soil	1	0
2.	Red sand, no Pleistocene shells	0	6
1.	Chalky-Jurassic boulder clay	4	0
	Water.		

The boulder-clay here was very similar to that elsewhere in the district, consisting of Jurassic clay containing much chalk, flint, and other erratics. Again, samples have been taken for future petrological work. This section is marked No. 42 on the map.

Eye.—As has already been described, brickearth overlies the marine gravel at Eye (Section No. 8) and is persistent all round this large section. No better description of the junction between the brickearth and the marine gravel could be given than that of Professors Marr and King in their paper on this pit (1928, pp. 210–12): "This chocolate-coloured rather sandy clay is seen resting on the gravels which are contorted for some depth beneath it, and in two cases marked channels in the underlying gravels are filled with this clay, while the sides of the channels are lined with gravel and sand which has been dragged in."

As is also mentioned by the authors of that paper, the brickearth also directly overlies the Oxford Clay on the north side of the eastern part of the pit, and at one point it contains a large inclusion of what may possibly be Chalky Jurassic Boulder Clay, consisting of chalky clay with flint and limestone pebbles contained in it. The identification of this "erratic" is far from certain, as the matrix does not consist of the usual Jurassic clay, but samples have been taken for future work and it may then be possible to express a more definite opinion.

The brickearth at Eye appears to be similar in every way to that at Yaxley, in colour, consistency, and apparently in the contained pebbles, and the writer believes that the two are contemporaneous. In fact this brickearth is almost universal in the district. Proceeding southward from Eye, it was seen in several of the brickworks round Whittlesey, and also can be traced as far west as Fengate (No. 9), and as far east as Coates (No. 10). It reappears in the March-Manea district, at Section No. 48, although it appears to be missing at Graysmoor (No. 44) and at Hobb's Bridge (No. 45). It is also absent south of March at Section 20, but reappears to the west of Wimblington at Section 22 and at three other shallow sections near-by, and at Section 41. Further east, as already mentioned, there is a little brickearth at Wimblington Common (No. 17), and also a little in Section 18. At Honey Hill (No. 29) there is a little grey brickearth which may possibly be the same material, but it appears to be absent at Sections 11 and 30 near Manea. To the southward, a little gray dusty brickearth appears at the top of the Carter's Bridge Section (No. 23), as at Honey Hill. No detailed work has been done by the writer as far south as the neighbourhood of Somersham, but it might be mentioned here that the brickearth in the whole Peterborough-March district is extremely similar to that near the top of the Traveller's Rest section near Cambridge, as Professors Marr and King have pointed out (1928, p. 211).

In fact the suggestion of these writers that the brickearth is of glacial origin in some sense seems almost certainly correct. In all

the sections in which this deposit has been studied by the present writer it contains marine shells only at Eye, where they have obviously been derived from the underlying gravel, it is never well-bedded, and never has the appearance of a marine or freshwater deposit, and it is far too stony, at least in most sections, to be of aeolian origin. Some form of glacial origin is therefore highly probable, but it is not possible to be more definite than this about its exact origin until further investigation has been made of its petrography.

Glacial Sequence.—From the evidence at Yaxley alone, it might appear that the Chalky-Jurassic Boulder Clay and the brickearth represent different phases of a single glaciation, but if, as is believed to be the case, the comparatively temperate marine gravel of March is intermediate in age between the two, we must be dealing with two separate glaciations. It is pretty evident that the fauna of the March Gravel represents cold conditions, but it is not cold enough to have lived during a glaciation over the low ground of Fenland. Therefore the time occupied by the formation of the March Gravel represents a major retreat of the ice, if not an actual interglacial epoch. Although the Chalky-Jurassic Boulder Clay has nowhere been seen underlying the March Gravel during the present field-work, the March Gravel is full of Jurassic fossils, and also contains erratics, which have apparently been derived from the Chalky-Jurassic Boulder Clay, and therefore the boulder clay is considered to be pre-March Gravel. This also appears to be the opinion of previous workers in the district, as already stated. On the other hand the brickearth has been seen in many sections to overlie the March Gravel, and has never been seen beneath it, and this brick-earth is certainly post-March Gravel. The supposed boulder clay overlying March Gravel as seen by Seeley (1866, p. 470) was probably the brickearth. The general sequence connecting the glacial with the marine deposits in the southern Fens appears to be :—

3.	The brickearth . . .	Arctic.
2.	March Gravel . . .	Cold-temperate.
1.	Chalky-Jurassic Boulder Clay	Arctic.

No deposit similar to the Upper Chalky Boulder Clay of East Anglia has been recognized so far in the southern Fens, but this does not necessarilly imply that there have only been two glaciations here.

5. Relation to Implementiferous Deposits.

A few implements have been found in the March area, and they have been examined by Mr. Miles Burkitt and Dr. K. S. Sandford, but only two of these implements appear to be dateable with any safety. These are shown in Figs. 4 and 5, and I would like to take this opportunity to express my thanks to Mrs. Burkitt for being so kind as to prepare these figures for me.

Bedlam Farm.—This flake (Fig. 4) was found on the surface by Mr. Walker, and the patina is of a yellowish colour. The striking platform is unfacetted, and is reminiscent of Clactonian work. The length of this flake is 67 mm.

Wimblington Common.—This flake (Fig. 5) was found by Mr. Walker and myself on a tip heap in Griffin's Pit (No. 17), and some of the matrix adhering to the flake appears to belong to the gravel. There is much angular flint in the upper part of the marine gravel in this section, most of which is in the same slightly patinated condition as this flake. The platform on this flake is facetted, and the work is on the whole reminiscent of Levallois industry, being similar to flakes from the Lower Loess at Tellier's Pit, St. Acheul, which are in Dr. Sandford's collection at Oxford. Length 76 mm.

Linwood Farm (No. 28).—It is most unfortunate that this pit was closed down before the writer had the opportunity of studying the section, as several worked flints have been obtained here by Mr. Walker. One flake is more reminiscent of Levallois work than that of any other period, and he also found two small scrapers which show practically no patination at all; they belong to a type which might have been made at any date between the Aurignacian and the Iron Age, but if more could be found out about this section, they might be of value. All these three were found within two or three feet of the surface, and it would have been interesting to work out this section in detail.

All the implements from these three sections are in the possession of Mr. F. M. Walker of Manea.

In the March Memoir (1893, p. 113) there is an interesting record of an implement which was said to have come from a depth of 20 feet below the surface at New Park, March. It is inferred that it was found in the marine gravel. No figure is given in the Memoir, but it is described as "almond-shaped", and its dimensions are given as $7\frac{1}{4}$ by $3\frac{3}{4}$ inches. From the text it seems probable that there may be a photograph of this implement in the possession of the Geological Survey.

A long discussion of the relation between the March Gravel and the implementiferous deposits near Cambridge would take up too much space in the present paper, but it is the writer's opinion that the conclusions reached here are in general agreement with Professor Marr's ideas. It should first be pointed out that the "*Cyrena*-Formation" of S. V. Wood, jun. (1882, pp. 692, 698), is probably of stratigraphical value so far as the March, Hunstanton, and Nar Valley beds are concerned, but it is hoped to discuss this question more fully at a future date. The writer considers, however, that the Barnwell Beds near Cambridge which contain *Corbicula* should not be included in such a "formation", because of discrepancies of faunal associations and of implements, which have been discussed in the present paper. The various papers by Professor Marr will not be discussed here in detail; it will be sufficient to say that the

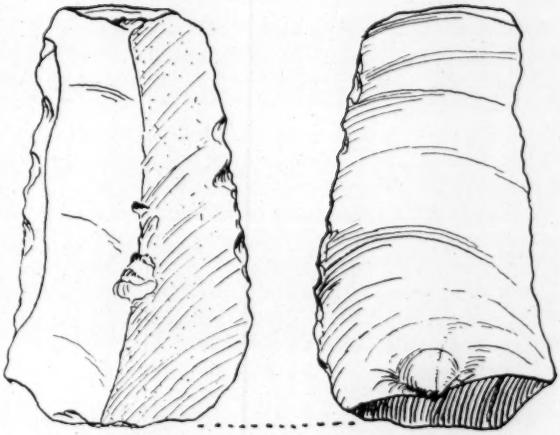

FIG. 4.—Flake from Bedlam Farm.

Bulb on reverse side.

FIG. 5.—Flake from Wimblington Common.

writer is in complete agreement with Professor Marr's correlation of the March Gravel with the Observatory Terrace at Cambridge (1928, pp. 114, 115), which is of general "Mousterian" date (Marr, 1917, p. 68), and a river gradient, for instance, between Cambridge and Manea is a likely one (about 4 feet per mile), quite apart from the faunal (climatic) and cultural similarity between the two deposits. As the terraces at Cambridge are compound, it would admittedly be desirable to discuss this correlation at greater length, but our present meagre detailed knowledge, especially concerning the cultural date of the March Gravel, would not justify such discussion at the present stage. The important point is that, if this correlation is correct, the *Corbicula* Horizon (Lower Barnwell Village Bed) near Cambridge is earlier than the Observatory Terrace, and therefore also earlier than the March Gravel horizon, in spite of the fact that *Corbicula* is found in the March Gravel.

6. Chronology.

In summary, we can now trace at least some of the physical events which have taken place in the southern part of Fenland during the Pleistocene.

Chalky-Jurassic Boulder Clay.—The earliest deposit which has been seen so far is this boulder clay, which undoubtedly represents glaciation from north-west to south-east. There is no evidence that it is of marine origin, and it has all the appearance of a typical product of land-ice. That the mean level of the sea was relatively much lower during this glaciation than it is at present seems probable, because this boulder clay frequently descends below present Ordnance Datum level, as at Stonea and Crane's Farm. There is no direct evidence in the southern Fenland as to the greatest depth to which this boulder clay can be traced, but the records of deep borings at Boston, in northern Fenland, are important. There was much controversy about the significance of this boring, but the main results were that, according to Skertchly's interpretation (1877, p. 217), emergence could be proved to the extent of 150 m. (about 480 feet), but according to that of Jukes-Browne (1879, p. 420) to about 50 m. (about 162 feet). We will be safe in concluding that this glaciation was accompanied by an emergence of at least 33 m. (100 feet), and this conclusion is not based solely on the evidence of the one boring at Boston, but appears to be supported by other deep borings elsewhere.

March Gravel.—There is no direct evidence now visible in our district of the relation of the marine March Gravel to the Chalky-Jurassic Boulder Clay, nor of any intervening beds between the two, but boulder clay was seen underlying the marine gravel by both Seeley and Clement Reid (see the March Memoir, 1893, pp. 8, 109). By analogy with the Cambridge District, a warm period came between the Chalky-Jurassic glaciation and the March Gravel period. The March Gravel is considered to represent a submergence

(relative to existing sea-level) of from 10 m. (32 feet) to 12 m. (40 feet), and the climatic equivalent of the shells is approximately Denmark or Southern Norway. It is considered probable that a slightly modified form of *Corbicula consobrina*, usually a fresh-water species, adapted itself to life with true marine forms, but unfortunately practically nothing is known yet of the contemporary flora or land-fauna of this period. There is some evidence that the time of the formation of the March Gravel may correspond with some Levallois stage in the sequence of human culture.

Brickearth.—The next definite stage following the deposition of the March Gravel is represented by the Brickearth, which is sometimes stony and never laminated. As this deposit does not appear to be a typical boulder clay, it is doubtful whether it represents an extension of land-ice over the whole of Fenland. It is difficult at the moment to understand its exact mode of formation, but it does appear to be in some sense of glacial origin. Like the older boulder clay, it is known to descend below Ordnance Datum level and, as there is no evidence that it is of marine origin, it was presumably formed during a period of emergence.

From the facts so far collected in the southern Fens, the following sequence can be made out :—

Sea-level.	*Deposit.*	*Climate.*	*Implements.*
3. Negative. ?	Brickearth.	Arctic.	?
2. Positive. 10–12 m. (32–40 feet).	March Gravel.	Cold-temperate.	? Levallois.
1. Negative. ? 33 m. (100 feet.)	Chalky-Jurassic Boulder Clay.	Arctic.	?

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On the Genus Cyclocystoides.

By James L. Begg, F.R.S.E., F.G.S.

(PLATE XI.)

THE classificatory position of the genus *Cyclocystoides* remains shrouded in doubt. This is due in some measure to the paucity of the material available for study and the unsatisfactory state of preservation of many specimens. The greatest difficulty is, however, due to the fact that it presents many features which are unique, and which make its correlation with known groups far from a simple matter.

Palaeontologists have suggested its reception into various orders. Hall (1851) and Raymond (1913–14) have proposed the Crinoidea or Cystidea. Billings and Salter (1858) refer it to a new genus of Echinodermata remarking " either a starfish or cystidian, the ossicles recalling a cystid, the central disc recalling a starfish ". Bather (1900) places it with the Edrioasteroids. Foerste (1925), in redescribing certain American forms, does not commit himself in the matter of classification.

Our earliest knowledge of the genus is a contribution by Hall (op. cit.). He thought it might be the marginal ring of some sessile crinoid and named it *Anteseptus*. Raymond (op. cit.) considers that in the various specimens recorded from American localities some ten species may be accepted.

American records show the genus to have a vertical range from the Lowville in the Black River Group, with occurrences at several stages in the Trenton, till finally it makes its exit in the Hudson River Group. The only other known occurrence up till the present is that of a British form from the Llandovery of Wales.

During the summer of 1933 four specimens of *Cyclocystoides* were discovered by Mr. A. Lamont, of Glasgow, and myself in the Starfish Bed of the Drummuck Group (Ashgillian) in the Girvan District. Three of these belong to a new species. The other, no doubt, is also new, but too fragmentary for description.

In one instance we were particularly fortunate in finding the two plates, dorsal and ventral, in juxtaposition ; the central disc is in a particularly good state of preservation, a thing of rare occurrence. Further, this specimen reveals a symmetrical relationship between central disc and submarginal area, which has not hitherto been detected.

Cyclocystoides decussatum sp. nov. (Pl. XI, Figs. 1–5.)

Description.

Lower Plate (B.G. 2004).[1]

Complete, oval, central disc composed of plaited integument, disposed in 32 radii. Each ray is probably divided medially, for

[1] Catalogue number in Begg Collection.

the greater part of its length, by a thin narrow longitudinal ridge. On either side of this ridge, rude rounded knobs form broad transverse elevations. These cross ridges are separated by deep, narrow furrows which tend to be more or less oblique with reference to the length of the ray. The broadest part of each ray is about one-third the distance from its proximal end, and from this point it contracts to its distal end. The rays fall into four distinct orders.

(1) Four rays in the form of a St. Andrew's Cross meet at and occupy the central area of the disc.

(2) Four shorter rays occupy the centre of the area thus left, and coincide in direction with the longer and short axis of the disc.

(3) Eight still shorter rays occupy the centres of the areas now remaining.

(4) Sixteen very short rays occupy the sixteen remaining areas and complete the disc.

This disc attains a greater symmetry in the distribution of the rays than any form which I have seen figured, and it should be noted that neither centrally nor in any part of the disc is there evidence of an oral or anal orifice.

The submarginal area is composed of thirty-two plates or ossicles corresponding to an equal number of rays on the central disc. The inner elevated ring of ossicles is not preserved in any of our specimens, but its presence is inferred from the hollows remaining, and impressions of the ossicles show that the usual tuberculations were present, packed closely together.

In one instance (B.G. 2004) they form a linear arrangement at the inner wall of the hollow just below the edge of the disc which slightly overhangs. The interstices between adjoining ossicles, which Raymond (op. cit.) suggests were occupied by cartilage or muscular attachments, are in our specimen represented by bars of matrix crossing the hollow cast.

The outer ring of the submarginal area is a platform with spoon-shaped depressions. Around each depression runs an elevated well-rounded rim.

Each ossicle bears two, or three, of these depressions ; observations reveal three contiguous ossicles each bearing three depressions followed by three ossicles each bearing two, and so on.

Again, five depressions may occupy two spaces, the central one being in alignment with the partition in the inner ring of ossicles.

The outer part of the submarginal ring forms the canal which surrounds the whole animal. The small imbricating plates, well described by Raymond and Foerste, which cover the canal are not preserved in our specimens.

According to Raymond there was a double series of these plates—(1) a vertical one rising just outside the depression, and (2) another resting upon this series and the inner side of the depression in the form of a covering roof. According to Foerste (1924) these plates could be moved outwardly or inwardly and so admit of, or prevent, access to the canal.

Beyond the spoon-shaped depressions, and sloping downward and outward, there is a series of sinuous threads or possibly of imbricating plates. The first and upper row is much larger than the others; its sinuosities appear to alternate with the spoon-shaped depressions or, at least, they are not in alignment and no doubt they compare with the "spout-like appendages" which Foerste (op. cit.) describes in the type of *C. huronensis*.

In one of our specimens (A.L. 2007) we have preserved casts of the pores which connected the spoon-shaped depressions of the canal with the central disc. They are visible on each side of the hollow cast of the ossicle ring; distally they originate on the inner side of the rounded rim which encircles each depression. On the inner side they are seen to pass into ducts below the surface of the disc. There should no longer be any doubt about the existence of these pores.

Billings (op. cit.) says that pores were present in *C. halli*. Some authors have surmised, but could not detect their presence. Foerste (op. cit.) says, "apparently these radial lines [of the disc] tend to terminate opposite twice their number of spout-like appendages [on the periphery external to the zone of spoon-shaped depressions] No passage connecting the radial lines with the spout-shaped appendages is known."

But Raymond (op. cit.), in describing a specimen of *Cyclocystoides* collected by himself from the Lower Lowville, says it is "badly preserved; some of the weathered plates seem to show the pores which penetrate the plate longitudinally and connect the cup-shaped depressions with the disc".

Upper Plate (B.G. 2005).

This plate was found covering the plate just described (B.G. 2004) and not underneath it. While it is less complete than its neighbour, still it shows all the essential parts in a fairly good state of preservation. Centrally there is an ill-defined knob or tubercle surrounded by a few others less distinctly visible. The median area is occupied by round or polygonal plates, evidently in a radial arrangement, corresponding to the lower plates, but not so well defined. The marginal area corresponds to the submarginal area of the lower plate. There is here no evidence of an outer zone of plates. It is subdivided like the lower plate into thirty-two compartments. The inner ring is more deeply excavated to accommodate the ossicle ring, but the outer ring which covers the canal is less deeply excavated and it bears thin radially directed lines like those found in certain American forms. There is no evidence of a stem attachment on either plate.

Dimensions (B.G. 2004).

Total length of long axis . . .	16·5 mm.
Total width of short axis . . .	14·0 ,,
Inner ossicle ring (measured radially) .	1·25 ,,
Outer ring, canal, (measured radially) .	1·0 ,,

Remarks.

Our species bears little resemblance to the Welsh form *C. davisii* Salter. Among American forms it has affinities with *C. huronensis* Billings and *C. halli* Billings. Neither of these species, however, appears to show a correspondence between the radii and the ossicles in the submarginal ring. Foerste in the former species counted in a given area fifteen rays in the central disc to eighteen submarginal plates or ossicles. Further, in the part preserved of the submarginal ring, he counted forty-five plates and concluded that a complete specimen would have fifty-nine. In the American forms the normal number of spoon-shaped depressions to each plate or ossicle is two, with an occasional narrower ossicle bearing only one. Our specimens never show fewer than two depressions to each ossicle, and quite often there are three present.

I suggest that our specimen should be named *C. decussatum.*

Interpretation.

If I interpret the American authors correctly in their description of *Cyclocystoides*, they all, with the exception of Foerste (op. cit.), consider the lower plate as having lain uppermost ; the disc as being an exposed surface, and the plate which I determine upper, as passing underneath it. But Foerste (op. cit.), while agreeing with the view here expressed, calls the upper plate ventral and the lower plate dorsal, probably by analogy from the dorsal and ventral relationship in the Crinoidea.

The lower plate, which evidently had a flat base, contained all the organs essential in the economy of the animal and although not attached rested firmly on the sea floor. This plate should, I think, be termed ventral. Bather (1913) describes two very remarkable species of cystids from the same bed, *Cothurnocystis curvata* and *C. elizae.* In the specimens of *Cyclocystoides decussatum* the present writer is struck by the resemblance of the spoon-shaped depressions to the grooves with their cover-plates in the subvective system of Bather's two species, particularly in the case of *C. elizae.*

These grooves had their upper part movable so as to admit or exclude the entrance of water. With the outlet closed, bellows-like muscular action by raising the obverse or upper surface drew water into the interior. A contracting of the muscles accompanied by a simultaneous closing of the grooves and opening of the anal plates forced exhaust water through an outlet at the end of the gut.

In the economy of *Cyclocystoides* probably similar processes obtained. There appears common consent that water had access to the canal through cover-plates. It is now clear that pores existed connecting the spoon-shaped depressions with ducts beneath the surface of the disc, and water could therefore be brought into these. The presence of an anal opening has not been proved in any known species. There is no evidence of an orifice in our upper dorsal plate ; that an orifice or outlet will be found in the lower ventral part, is,

I think, extremely improbable as stagnation would result in such a case, because currents of water would have no access to remove the faecal material. When water bearing food and oxygen had been drawn in, the inlet would probably close. After sufficient time had been allowed for absorption and digestion, the inlet (now outlet) would reopen and repeated bellows-like muscular action between the upper and lower plates would insure complete expurgation.

The under plate doubtless remained fairly steady; the upper plate most authors agree was more or less flexible, due to the imbricating nature of the plaited integument. In consequence, it would rise or fall with muscular expansion and contraction. Possibly the principal function of the ossicle ring through which the pores passed, was to act as a strengthening girder.

From the foregoing I conclude that *Cyclocystoides* has its affinities with the Cystidea and may even represent a distinct order of that class.

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A New Species of *Conularia* from Girvan.

By ARCHIE LAMONT, M.A., B.Sc., Carnegie Research Scholar, University of Glasgow.

(PLATE XI).

Family CONULARIIDAE Walcott.

Genus CONULARIA Sowerby, 1818, ex Miller MS.

Conularia scotica sp. nov. (Pl. XI. Figs 8, 9.)

DIAGNOSIS.—Shell small, thin, tapering more rapidly towards apex. Marginal grooves well developed, with raised rims between which there is a fine longitudinal furrow. Faces, flat to slightly concave, ornamented with strong transverse ridges, evenly distributed, narrower and less rounded than the interspaces, forming rounded angles of about 135° and also bending forward at lateral ends.

A single median longitudinal rib, forming the "segmental line", finer in calibre than the transverse ridges, traverses each face.

Apertural lobes and apex unknown.

Dimensions.—Length of specimen, 9 mm. ; greatest facial width, 2·9 mm.

Holotype.—Hunterian Museum, University of Glasgow.

Horizon and Locality.—Mudstones (Caradocian), Balcletchie, Girvan.

Remarks.—The new species may include some of the fragments mentioned by Miss Slater (1907, p. 33) under *Conularia* sp. The transverse ridges have the same flexure, but are closer together, 34 in 9 mm. Ridges fully observed are smooth. The apical angle appears to be as much as 25°, but towards the aperture the sides are increasingly parallel and only make an angle of about 17°. Adjacent faces probably slightly unequal in width.

On the left posterior edge of the specimen (Fig. 1), the narrow,

Fig. 1.—*Conularia scotica* sp. nov., showing median longitudinal rib. × 5.

longitudinal furrow of the marginal groove is seen lying between rims much broader than itself. Part of one rim is seen carrying an additional fine longitudinal striation. The rim-material conceals the lateral extension of the ridges. On the right side of the specimen the superficial rim-material has been detached. The ridges seem to swell slightly where they encroach upon the marginal groove, within which they are somewhat bent forward.

Affinities.—An important feature is the median rib, probably corresponding to that which appears in certain other species. Such a rib is taken to represent the presence of an internal septum. Miss Slater (op. cit., 21–2) describes one British species with single rib, *Conularia tenuis*, Lower Carboniferous. Dr. Reed (1933, 355–7) describes two species with this feature, *C. slateri* and *C. mirifica*, Drummuck Group (Ashgillian), Girvan. We may associate the new species with these.

Miss Slater (op. cit., 13) includes *Conularia tenuis* in the same line of descent as forms with double median rib from Ordovician

and Silurian horizons, but the new evidence points to the existence of two distinct groups.

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EXPLANATION OF PLATE XI.

Cyclocystoides decussatum sp. nov.

FIG.

1.—A.L. 2007. *Cyclocystoides decussatum* sp. nov. (*a*) Casts of pores. (*b*) Matrix indicating the position of the ossicle joints. × 2. "Starfish Bed," Drummuck Group (Ashgillian), Girvan.

2.—B.G. 2005. *C. decussatum* sp. nov. Cover plate found covering B.G. 2004 (Fig. 3). × 2. Same horizon and locality.

3.—B.G. 2004. *C. decussatum* sp. nov. Central disc and submarginal ring; marginal zone not preserved. × 2. Same horizon and locality.

4.—A.L. 2006. *C. decussatum* sp. nov. Lower plate; arrow indicates the marginal zone with the "spout-like appendages" of Foerste. × 2. Same horizon and locality.

5.—*C. decussatum* sp. nov. Enlarged drawing of (*a*) Marginal zone, (*b*) Submarginal area with spoon-shaped depressions, casts of pores, and cast of space between ossicles.

Cyclocystoides halli Billings.

6.—*C. halli* Billings. Drawing copied from Salter and Billings, *Canadian Org. Rem.*, Decade iii (1858), pl. x. Here the authors err in showing, by dotted line, the upper plate passing under the lower plate.

Cyclocystoides huronensis Billings.

7.—*C. huronensis* Billings redescribed by Foerste. × 3. After *Upper Ordovician Faunas of Ontario and Quebec*, 1924, vi, fig. 3.

Conularia scotica sp. nov.

8.—*Conularia scotica* sp. nov. × 2. Mudstones (Caradocian), Balcletchie.

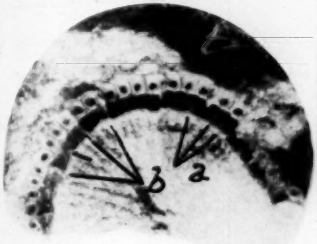
9.—*C. scotica* sp. nov. External mould. × 2. Same horizon and locality.

Notes on the Shell Musculature of *Gryphus vitreus* (Born).

By IAN COX, B.A., Sedgwick Museum, Cambridge.

IN work on fossil brachiopods the present writer has found that descriptions and more particularly figures of the musculature of living froms are insufficiently explicit for parallels to be drawn with fossil specimens.[1] These notes are the result of dissections of specimens of the living Terebratulinid *Gryphus vitreus* (Born) from the Marine Biological Station at Naples, and are intended primarily to elucidate the accompanying figures, which it is hoped might be of some value to palaeontologists.

[1] The writer is greatly indebted to Professor J. Stanley Gardiner, F.R.S., and Dr. E. J. Allen, F.R.S., for confirming the strange lack of literature with regard to the details of musculature of *Gryphus vitreus*, and to the former for his kindness in reading this manuscript.



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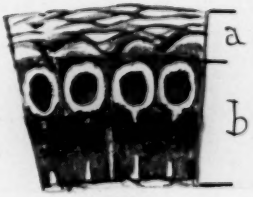

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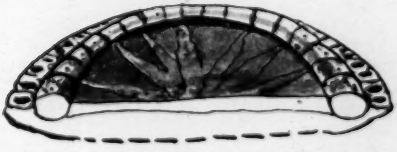

6

Cyclocystoides and Conularia.

[To face p. 226.

The general aspect of musculature in living brachiopods is best treated of in Thomson's *Brachiopod Morphology and Genera* (*Recent and Tertiary*), where many references are to be found. The nomenclature of that work is adopted in these notes; hence the brachial valve is regarded as dorsal and the pedicle valve as ventral.

(1) Muscles of the Shell.

The shell is held closed by the *adductor muscles* (*a* in the text-figures). These are attached to the dorsal valve as six distinct bundles, arranged symmetrically three on each side of the median line, one pair being considerably smaller than the other two. The median line is raised here to a slight ridge or incipient septum. The muscular tissue of each bundle rapidly gives place to tendon. The tendons converge, first the three on each side becoming associated and finally the two thus formed joining into a main tendon at a point rather more than half the distance across to the ventral valve. The muscles are attached to the ventral valve as a single median bundle, elongated axially. Even at its attachment there, however, it retains its tendonous character and has very little, if any, muscle tissue.

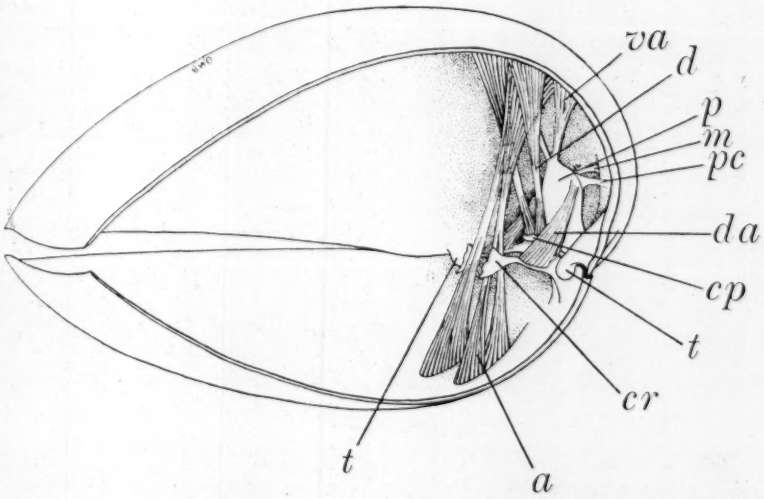

Fig. 1.—Dissection of *Gryphus vitreus* (Born) viewed from the left front to show the disposition of the muscles relative to the shell. The "body" is removed. Ventral valve uppermost. *a*, adductor muscle; *cp*, cardinal process; *cr*, base of brachidia; *d*, diductor muscle; *da*, dorsal adjustor muscle; *m*, median unpaired muscle; *p*, peduncle; *pc*, peduncular connective; *t*, tooth; *va*, ventral adjustor muscle.

The diductor muscles (*b*) are attached to the ventral valve on either side of and anterior to the adductor scar. They rapidly pass into tendon tissue as they run posteriorly and slightly converging

to the ventral surface of the cardinal process (*cp*), where they suddenly swell transversely before attachment. Here, as in the adductors, the true muscle tissue is restricted to a short length, but in this case it is lying ventrally.

(2) The Muscles of the Peduncle.

The muscles of the peduncle consist of two pairs and a single unpaired muscle.

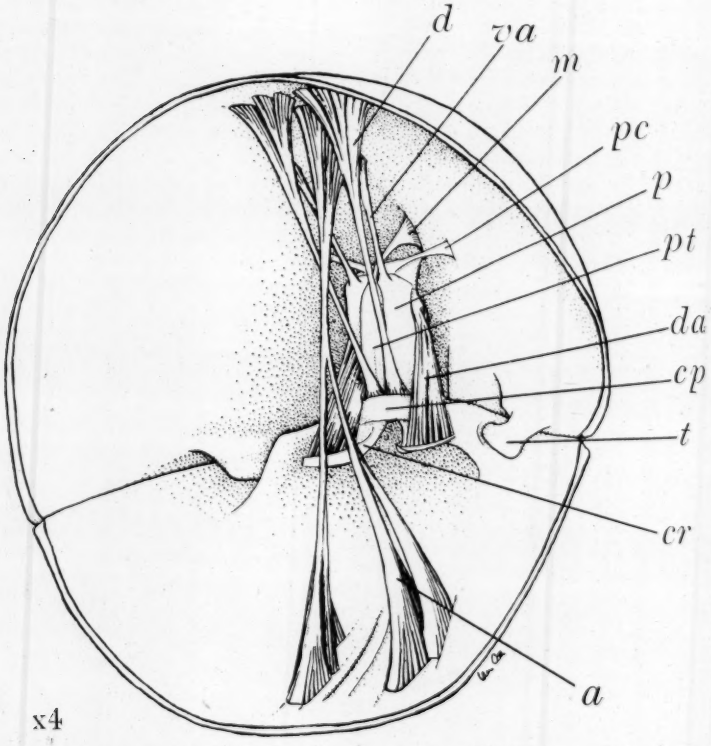

Fig. 2.—Dissection of *Gryphus vitreus* (Born), viewed from the left front, to show musculature. The "body" has been removed and the brachial loop broken off. Ventral valve uppermost. *a*, adductor muscle; *cp*, cardinal process; *cr*, base of brachidia; *d*, diductor muscle; *da*, dorsal adjustor muscle; *m*, median unpaired muscle; *p*, peduncle; *pc*, peduncular connective; *pt*, pinnate tendon; *t*, tooth; *va*, ventral adjustor muscle.

The dorsal adjustors (*da*) arise on either side of the peduncle (*p*) and just dorsal to its terminal swelling. They pass to the base of the brachidia (*cr*.) The dorsal adjustors consist of muscle tissue for all their length and have the shape of an acute angled triangle, with the apex at the peduncle.

The ventral adjustors (*va*) are attached with triangular bases to the ventral valve posteriorly to the scars of the diductors. They converge and run posteriorly into the base of the peduncle with the substance of which they are continuous. (This can be seen when the capsule of the peduncle is removed.) These muscles are tendonous for the greater part of their length.

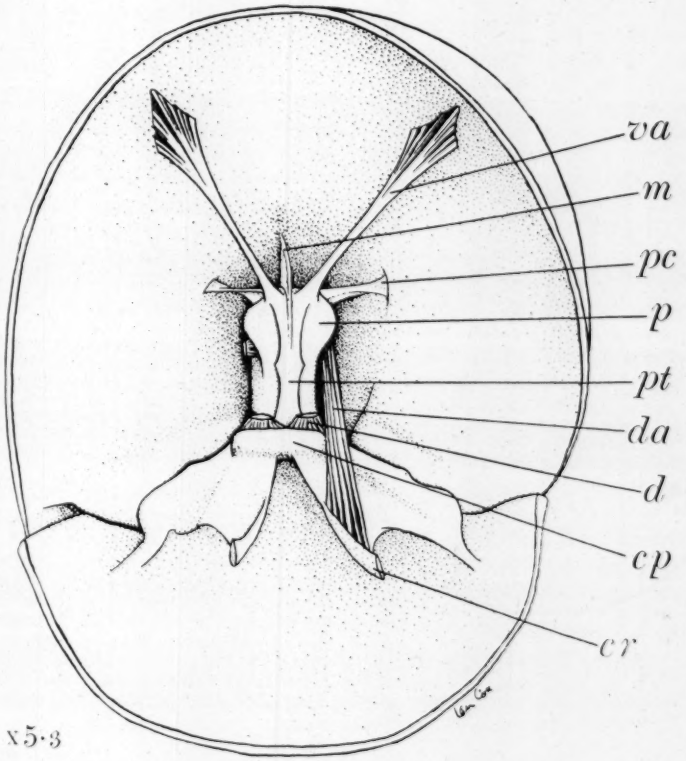

Fig. 3.—Further dissection of *Gryphus vitreus* (Born) viewed from the anterior to show the peduncle and its muscles. The diductor muscles and the right dorsal adjustor muscle are cut off short. The adductor muscles are removed. Lettering and orientation as in Fig. 2.

The median unpaired muscle (*m*) is attached to the ventral valve in a deep, axially elongated, scar situated medianly and directly posterior to the base of the peduncle. Its muscle tissue very rapidly gives place to a tendon which runs anteriorly between the tendons of the ventral adjustors, lying on but not attached to the base of the peduncle, and passes into an elongated leaf-shaped tendonous structure of cartilagenous consistency, for which the name *pinnate*

tendon is proposed (*pt*), lying closely associated with the capsule of the peduncle and extending for most of the length of that organ within the valve.[1]

The base of the peduncle is held in position by a plate of connective tissue (*pc*), which is continuous with the capsule. This plate has a semicircular shape, since it is horizontal in position and attached to the umbonal region of the ventral valve for all the distance posterior to the peduncle. The plate is very thickened where it joins the shell, but although it leaves a considerably transverse scar, it has no muscle fibres in its tissue. This structure, whatever may have been its origin, is not a muscle and the name *peduncular connective* is proposed for it.

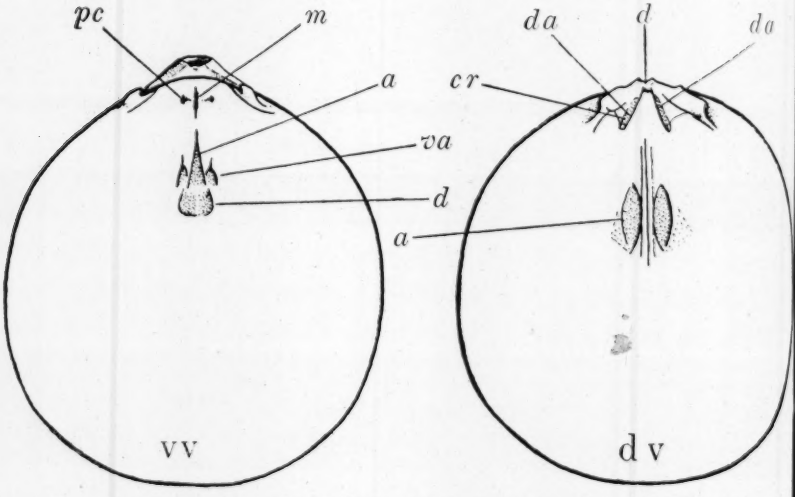

FIG. 4.—Diagrammatic sketch illustrating the area of attachment of the muscles in the valves of *Gryphus vitreus* (Born). *dv*, dorsal valve; *vv*, ventral valve; *a*, adductor scar; *cr*, base of brachidium; *d*, diductor scar; *da*, dorsal adjustor scar; *m*, median unpaired muscle scar; *pc*, scar of peduncular connective; *va*, ventral adjustor scar.

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[1] The median unpaired muscle in *Gryphus* seems only to correspond with the "ligament pédonculaire" (fig. 428) or "muscle pédonculaire" (p. 265) that Delage et Hérouard describe for "Magellania (Waldheimia)"; although they write (p. 265) "Quant au prétendu *muscle pédonculaire* nous avons vu que ce n'est qu'un ligament".

Starfish from the Welsh Borderland.

By W. K. Spencer, M.A., D.Sc., F.R.S., and
Theodore Groom, M.A., D.Sc.

(PLATE XII.)

SOME thirty years ago two species of Ophiuroidea and one Astereroid species were collected by one of us (Theodore Groom) from a small quarry near Rorrington in the Shelve District of Shropshire. There originally were several specimens but unfortunately the majority of these are now represented by plasticine casts only. The original material was mislaid during a loan and was recovered in part only last year. The finder's provisional description and figures, as well as his notes on the precise horizon and locality are still missing. It may be added that when, soon after the discovery of the specimens, their importance was realized an attempt was made to gain more material, the site was found to be built over. The specimens which are still to hand have been examined by Dr. Stubblefield, who says that there is no doubt that the matrix is that of the Spy Grit, a low Caradoc horizon, probably in the zone of *Mesograptus multidens*. It is from approximately this horizon that the majority of the British Ordovician starfish have been collected.

The new material contains two new species. One an Ophiurid, *Bohemura groomi*, and the second an Asterid, *Belaster simplex*. Both of these are allied to forms found in Bohemia. The third species, an Ophiurid, *Protaster salteri* Forbes, although not new in itself, shows new features. All the specimens of this form known hitherto have been collected in Wales and are of small size, probably only young stages of the form. Our specimens are larger and more mature. This agrees with a statement made to Spencer by Miss Elles that the general rule is that in the Shropshire Ordovician the fossils are larger than those of corresponding species found in Wales. Miss Elles suggests that this may have been due to the prevalence of active volcanic conditions in Wales. *Protaster* has not, as yet, been found in Bohemia.

The Ophiuroidea.

The Ophiuroidea are only discussed briefly here: a detailed description is being prepared by Spencer for his Monograph of the Palaeontographical Society.

Both belong to the group of Palaeozoic Ophiuroidea characterized by an open groove, alternate ambulacralia, and two rows of spines on side-shields, for which Spencer (*Mon. Pal. Soc.*, Part vii, 1930, 401) has suggested a family, the Protasteridae.

The generic and specific diagnosis given here are new. They are based on the more extensive descriptions prepared for the Monograph.

Genus Bohemura.

Genotype *B. jahni* Jaekel, 1903.

Generic Characters.—A Protasterid with a wide ambulacral groove, prominent groove spines, and weakly developed vertical spines. Vertebrae flat on dorsal surface. Mouth-angle plates stout.

A short description of the genotype was given by Jaekel in 1903. His material, which has been lent to Spencer by the authorities of the Prague Museum, is from a somewhat higher horizon (D 3) than the new material from Shropshire, and is much larger and better grown. Other material of the genus includes *B. granifer* (Whidborne) from the Lower Carboniferous of North Devon, and a new species from the Carboniferous limestone near Boulogne. *Bundenbachia beneckei* Stürtz is an allied form from the lower Devonian roofing slates of Bundenbach, Germany.

B. groomi, n. sp. Pl. XII, Figs. 1, 2, 2*a*.

Specific Characters.—Ossicles of disc stellate.[1]

Material.—Two plasticine casts, very possibly of one specimen and its counterpart, and a specimen in rock with its counterpart. This latter specimen is preserved partly as a mould and partly in calcite. The ossicles preserved in calcite are not fused together, as so often happens in fossil starfish, but preserve their original outlines with fine structural details. The specimen is selected as the holotype. The specimen in plasticine, the paratype, gives good ventral views.

Remarks.—The specimens are much smaller than those of the species named above, found in the later rocks, and obviously represent early stages in the evolution of the lineage.

Genus Protaster, Forbes.

Genotype *P. sedgwickii* Forbes, Lower Ludlow.

Generic Characters.—A Protasterid with the ambulacral noses near the ventral edge of the side-shields. Spines of ventral edge (groove-spines) weakly developed or absent.

The forms of this genus resemble somewhat closely those of *Taeniaster*, the typical American Protasterid. They differ, however, in the poor development of the groove-spines. In *Taeniaster* these spines are a well-marked feature. A further characteristic of *Protaster* is that the noses of the side-shields are typically thick and blunt. The genotype *P. sedgwickii* is known only from one specimen. Another single specimen was described by Hall as "*Eugaster*" *logani*. It is from the Hamilton beds (M. Devonian) of U.S.A. A later species is found in those beds in Devon, which were at one time placed in the Upper Devonian, but now are ascribed to the base of the Carboniferous. These beds contain many starfish found in the Upper Devonian and Lower Carboniferous of North America, and

[1] Spencer alone is responsible for the description and name of this species.

"*Eugasterella*" *bicatenulata* Ruedemann, from the Upper Devonian of North America, so very similar to the *Protaster*.

P. salteri Forbes. Pl. XII, Figs. 3, 3*a*.

Specific Characters.—Ambulacralia with elongate boot legs, proximal tube feet only slightly differentiated.

Material.—The plasticine casts (all the material known) are from four specimens, one cast showing the dorsal surface and three the ventral surface.

Remarks.—This form very definitely links up the Ordovician species with the genotype. Until recently only the smaller forms from Welsh localities were known and they presented features not easy to understand. Now that we know both the younger and older stages the lineage history of *Protaster* is much easier to follow. Sollas and Sollas (*Trans. Roy. Soc. B.*, 1912, 224) briefly describe under the name *P. groomi* the mouth frame of one of Groom's specimens. A further specimen is in the British Museum (Nat. Hist.). It was found on the roadside in the same district as our specimens. Dr. Stubblefield tells me that the matrix shows that the form is of the same horizon as those discovered by Groom.

ASTEROIDEA.

The Asteroid is a new species of the genus *Belaster* Spencer, 1916. The only species hitherto described is *B. ordovicus*, from the U. Ordovician (Ashgillian) of Girvan, Scotland. The form is very rare in the Scotch beds, being represented by only one specimen out of more than 700 star fish found there.

A second specimen, hesitatingly placed by Spencer, op. cit., 74, in the species, is not a *Belaster* but a *Siluraster*.

Belaster belongs to the family Hudsonasterdae, which contains the most primitive forms which are true Asteroidea.

Undescribed Bohemian forms allied to this new species, if not identical with it, have been sent to Spencer for examination from Prague. They were collected in the stage Dγ 1, an horizon somewhat lower than that of the specimen described here. It seems also probable that the so-called *Hudsonaster matutinus* (Hall) from the Trenton of North America belongs to this genus. If so, it is just possible that the species originated in Western Europe, travelled westward to America, and eventually reached Girvan, arriving in Europe for a second time.

B. simplex n. sp. Pl. XII, Fig. 4, Text-fig. 1.

Specific Characters.—A *Belaster* in which the proximal supero-marginalia are not markedly larger than the immediately succeeding supero-marginalia.

Material.—One specimen showing a mould of the dorsal side.

Remarks.—The specimen gives new knowledge of the structure of the disc. This was very imperfectly preserved in the Girvan

specimen. It is now seen that almost the whole of the disc was occupied by a circlet of comparatively large plates arranged around

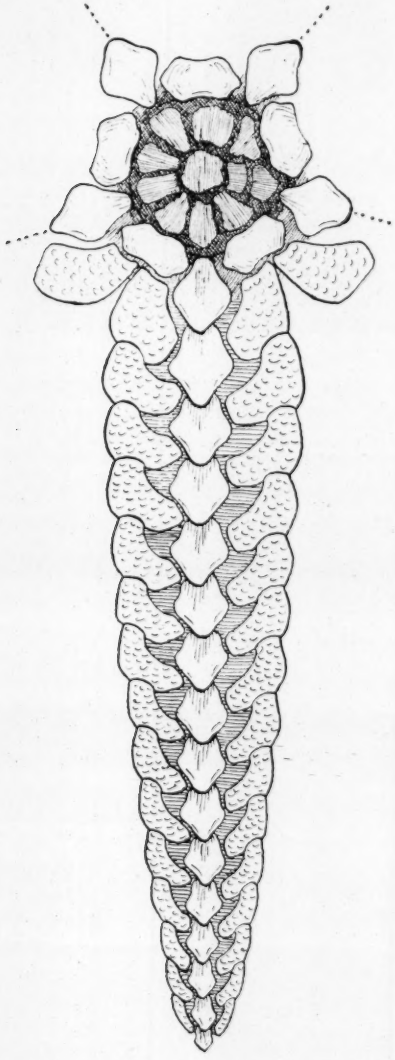

FIG. 1.—*Belaster simplex* n. sp. One arm and disc. The disc organ is sunk and shown shaded in black lines.

a central plate in the typical " Hudsonasterid " manner, and that probably this disc system is a definite functional organ.

An examination of the British and Bohemian "Hudsonasterid" material and a comparison with the figures of the American specimens shows that the disc system can lie level with the general disc surface or be sunk well beneath it. In this Shropshire specimen it is well sunk. It seems probable that the "disc system" had an up and down motion comparable to that of the central disc area in *Astropecten* and other recent starfish where the movements are known to be associated with respiration. Spencer discovered a somewhat similar system, somewhat more obviously specialized, in the Girvan Hudsonasterid *Girvanaster*. It now seems possible that a disc organ was a common feature in these primitive Asteroidea. The somewhat heavy plating of the form makes the provision of a specialized respiratory area readily understood.

Conclusion.

The new forms strengthen considerably the relationship between the Bohemian starfish and those of Wales and the Welsh Border. Bohemian starfish are known from the Llanvirn (Dγ 1) and the Caradocian (D 3). Welsh starfish are known from the Arenig, Llanvirn, and the Caradocian.

The Bohemian starfish from the Dγ 1 horizon are the earliest known considerable assemblage of starfish. Some of these have been described briefly by Jaekel. Spencer, to whom the detailed description of the Bohemian forms has been entrusted, has now completed his preliminary study. These show that the fauna can be regarded partly as a summit fauna of a primitive type which apparently does not survive the Llanvirn, and partly an assemblage of the early representatives of lineages which carry on into later rocks. One representative of the summit fauna *Palaeura* has been discovered recently by Dr. Stubblefield (in Whittard, p. 340, 1931) in the Upper Hope Shales of Shropshire.

Belaster simplex, on the other hand, is a representative of a lineage which can be traced both upwards and downwards. The occurrence in the Caradocian of Wales links its early appearance in Bohemia with the later occurrence in America and Scotland.

The starfish from the Bohemian D 3 horizon are *Bohemura jahni* Jaekel and *Siluraster perfectus* Jaekel.

Bohemura jahni is now shown to be represented by a less well-developed species in rocks at a lower horizon in the Welsh Borderland. The second species, *Siluraster perfectus*, has now been studied by Spencer. It is identical with a starfish occurring quite frequently in the Caradocian of Wales and the Welsh Borderland described by Spencer under the name *Caractacaster caractaci*. It should be called *Siluraster caractaci* (Gregory) and Spencer's name *Caractacaster* discarded.

Other resemblances between the faunas suggesting the presence

of a submarine bank stretching westward from Bohemia through Wales will be discussed in a later communication.

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EXPLANATION OF PLATE XII.

Fig.
1.—*Bohemura groomi* n. sp. Dorsal view, natural size.
2.— ,, ,, Ventral view, natural size.
2*a*.— ,, ,, The same specimen as in Fig. 2. × 4.
3.—*Protaster salteri* Forbes. Ventral view, natural size.
3*a*.— ,, ,, ,, The same specimen as in Fig. 3. × 4.
4.—*Belaster simplex* n. sp. Dorsal view, natural size.

Notes on a collection of *Dentalium neohexagonum* S. and P.

By D. K. Greger.

THROUGH the kindness of a correspondent in Southern California, the writer recently acquired a series of 320 superb examples of *Dentalium neohexagonum* S. and P. collected from the Fernando formation of that state. The following somewhat detailed account of the variations occurring in the collection may prove of interest to students of the Scaphopoda. Our study of this series is supplemented by the addition of other material of the species, collected by Charles Sternberg, from the Pleistocene in the vicinity of San Quintin, Baja California, Mexico, and a few examples of the species, now found living off the California coast, dredged by Henry Hemphill.

Average and Maximum Measurements.

Length (Chord): average 28 mm.; maximum 33 mm.
Arc: average 2·5 mm.; maximum 3·2 mm.
Diameter of aperture: average 2 mm.; maximum 2·7 mm.

Number and Character of Longitudinal Ribs.

Specimens with normal, six, ribs, 168 or 52½ per cent.
Specimens with seven ribs, by bifurcation of dorsal rib, 116 or 36¼ per cent.
Specimens with eight or more ribs, by intercalation and bifurcation, 36 or 11¼ per cent.

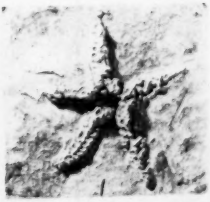
Characters of Apex.

Apex entire, 108 specimens.
Apex with dorsal V-shaped notch, 8 specimens.
Apex with ventral V-shaped notch, 40 specimens.
Apex with dorso-ventral notches, 102 specimens.
Apex with "plug and pipe", 62 specimens.

1

3A

3



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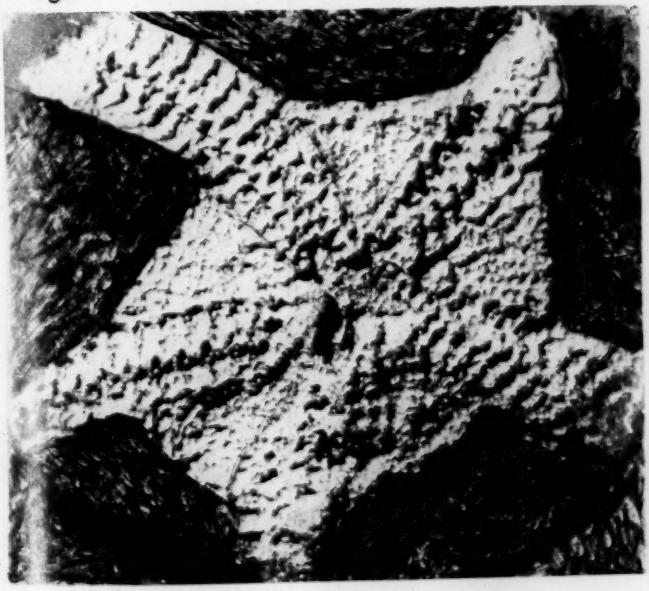

2A

STARFISH FROM THE WELSH BORDERLAND.

[*To face p.* 236.

A number of the specimens with protruding "pipe" were imbedded and sectioned longitudinally with the following results: Fracture and restoration occurs in the anterior of a number of the sectioned specimens and at the point of fracture the arrangement of the prismatic bundles is disturbed, producing a wavy effect in the inner nacreous layer, a more pronounced disarrangement in the middle layer, and amounting to a deep cleft in the outside layer. However, at the point of attachment of the "supplementary tube" there is no sign of disturbance of the prismatic bundles nor other visible evidence of restoration.

With a knowledge of the soft parts of the animal, and especially the position of the shell secreting glands, it seems to the writer that the restoration of any portion of the apex would be a physiological impossibility, for the apical portion of the shell would be practically vacated since the animal, with growth, had moved forward into more spacious quarters. There is no doubt in the writer's mind but that the so-called "plug and supplementary tube" or "inserted pipe" are the result of the varying resistance to the dissolving effect of sea-water on the quite different structures of the shell layers. The denser, nacreous inner layer offering greater resistance would stand out as an "inserted pipe" or as a "supplementary tube" after the middle and outer layers are dissolved away.

A Triassic Crinoid from Brazil.

By the late F. A. Bather, M.A., D.Sc., F.R.S.

IN "Faunas Triassicas do Brasil", by F. R. Cowper Reed (*Monogr. Serv. Geol. Brasil*, ix, 1929), there occurs on pp. 84, 85, a note by me on an obscure crinoid. This should have been accompanied by an illustration, but the drawing supplied was not reproduced. It has recently been returned to me by Dr. Cowper Reed, who concurs in my suggestion that it should now be published since the occurrence is certainly interesting and is liable to be overlooked among the wealth of lamellibranchs described by him, and beautifully figured on his plates by E. T. Talbot.

The crinoid fossil was among those collected by Dr. Euzebio de Oliveira, Director of the Brazilian Survey, at the locality Serrinha No. 29, in the State of Paraná. It was there associated with the lamellibranchs *Cuspidaria similis* (Holdhaus), *Pleurophorus* (?) *bispleura* Reed, *Pseudocorbula emerita* Reed, *Isocyprina curvata* Reed, *Myophoria* cf. *woehrmanni* Bittner, *Myophoriopsis martialis* Reed, *Myophoricardium* cf. *lineatum* Wöhrm., and *Gonodon* aff. *mellingi* Hauer.

These fossils show that the exposure belongs to "Horizon A", and the fauna of that horizon, though containing no species certainly identical with European species, "points undoubtedly to a Triassic

age for the bed and suggests the Upper part of the Middle or Lower part of the Upper stage of the Trias " (Reed).

The following is my original description, dated 22nd August, 1929 :—

An obscure imprint of a crinoid in a fragment of porous, fissile, buff-coloured rock with no other distinguishable fossils. The portions preserved are the lower or proximal part of the crown and a small proximal part of the stem.

The plates of the crown appear to have been disturbed so that it is impossible to determine either the boundary between cup and arms or any individual plates of the cup. In these circumstances it is more profitable to give a drawing of the appearances, made from a wax squeeze, than to attempt a verbal description. (Figure 1. × 2 diam.)

Fig. 1.

The angle formed by the axis of the stem with the median axis of the preserved portion of the crown may be due to shifting of the stem or to non-preservation of that part of the crown which may have lain to the right of the drawing. Whether the vague transverse markings in the drawing represent joints between the columnals, or whether they may not be accidental appearances unconsciously exaggerated is somewhat doubtful.

Even to suggest that this imprint may represent a young Encrinid is perhaps unwarranted by the facts ; but the relative proportions and the apparent attachment of the stem, as well as the bounding curve of the crown on the left of the drawing, are in harmony with the suggestion. The counterpart, had it been found, might have thrown more light on this obscure but interesting specimen.

REVIEWS.

ARTHUR'S SEAT: A RUINED VOLCANO. By T. C. DAY. pp. 75, with 32 plates and sketch-maps. Edinburgh: Oliver and Boyd, 1933. Price 2*s.* 6*d.*

TEACHERS and students of geology in Scotland are greatly to be envied for their opportunities for the study of volcanic phenomena. While it is probably true that no remains of an actual crater can be identified anywhere in the British Isles, the inner structure of volcanoes can be studied in innumerable places in central Scotland, and nowhere better than at Edinburgh, where Arthur's Seat affords a splendid though somewhat complicated example. The present delightful little book gives an account of it from the point of view of a student who, while knowing some geology, is not necessarily an advanced specialist. One of the most useful features is the explicit directions as to how to find the different exposures.

The work is naturally founded to a large extent on the well-known monograph by the late Dr. Peach, but is slightly less technical in its treatment and is therefore well adapted for amateurs, though without degenerating into the sloppily popular style that is unfortunately now becoming rather common. The thirty-two plates are admirable examples of geological photography, while the sketch-maps are beautifully clear.

GEOLOGICAL DIAGRAMS OF THE DORSET COAST. By G. M. DAVIES. Two sheets. London: Murby. No title or date.

THESE diagrams evoke pleasing reminiscences of the present writer's first introduction to geology, in the form of the coloured sections in a somewhat battered copy of the second edition of the *Geology of the Yorkshire Coast* by John Phillips, 1835, which happened to be in the library of his childhood's home. It would appear, however, that even this was not the first representation of the idea, which is found in a somewhat crude form in an even earlier work, Young and Bird's *Geological Survey of the Yorkshire Coast*, 1822.

The present publication consists of two sheets, one of which shows on a scale of three inches to the mile horizontally, and six inches vertically, the geological succession of the cliffs from Pinhay Bay, west of Lyme Regis, to Burton Cliff, east of Bridport. When coloured on the model of the Yorkshire sections this would give a good idea of the structure of this interesting line of coast and the Cretaceous overlap.